JOURNAL of the

Sanitary Engineering Division

BASIC REQUIREMENTS FOR MANUSCRIPTS

This Journal represents an effort by the Society to deliver information to the reader with the greatest possible speed. To this end the material herein has none of the usual editing required in more formal publications.

Original papers and discussions of current papers should be submitted to the Manager of Technical Publications, ASCE. The final date on which a discussion should reach the Society is given as a footnote with each paper. Those who are planning to submit material will expedite the review and publication procedures by complying with the following basic requirements:

1. Titles should have a length not exceeding 50 characters and spaces.

2. A 50-word summary should accompany the paper.

3. The manuscript (a ribbon copy and two copies) should be double-spaced on one side of 8½-in. by 11-in. paper. Papers that were originally prepared for oral presentation must be rewritten into the third person before being submitted.

4. The author's full name, Society membership grade, and footnote reference stating present employment should appear on the first page of the paper.

5. Mathematics are reproduced directly from the copy that is submitted. Because of this, it is necessary that capital letters be drawn, in black ink, 3/16-in. high (with all other symbols and characters in the proportions dictated by standard drafting practice) and that no line of mathematics be longer than 6½-in. Ribbon copies of typed equations may be used but they will be proportionately smaller in the printed version.

6. Tables should be typed (ribbon copies) on one side of 8½-in. by 11-in. paper within a 6½-in. by 10½-in. invisible frame. Small tables should be grouped within this frame. Specific reference and explanation should be made in the text for each table.

7. Illustrations should be drawn in black ink on one side of 8½-in. by 11-in. paper within an invisible frame that measures 6½-in. by 10½-in.; the caption should also be included within the frame. Because illustrations will be reduced to 69% of the original size, the capital letters should be 3/16-in. high. Photographs should be submitted as glossy prints in a size that is less than 6½-in. by 10½-in. Explanations and descriptions should be made within the text for each illustration.

8. Papers should average about 12,000 words in length and should be no longer than 18,000 words. As an approximation, each full page of typed text, table, or illustration is the equivalent of 300 words.

Further information concerning the preparation of technical papers is contained in the "Technical Publications Handbook" which can be obtained from the Society.

Journal of the
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

CONTENTS

August, 1957

Papers

DIVISION ACTIVITIES

Journal of the
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

SANITARY SEWAGE DISPOSAL FOR SUBDIVISIONS*

Paul W. Richards,[1] M. ASCE
(Proc. Paper 1333)

SYNOPSIS

One of the major sanitary problems lies in the satisfactory disposal of sanitary sewage from subdivisions. A discussion of the problem and some efforts directed towards its solution are given.

The sanitary engineer, in controlling environmental factors affecting health in fringe areas, must consider water supply, household waste disposal, insect and rodent control, air pollution, and many other potential health hazards—the same factors considered in urban areas.

Water supply is generally available to fringe areas from the neighboring central city. In most cases, other environmental factors in controlling health in fringe areas have been provided to some degree.

Many State health officials feel that sewage disposal in fringe areas is the greatest single problem confronting them at the present time. One aspect of this problem that many of us may not have considered in the past is that of financing fringe-area sewerage systems. Financing is a prime consideration in providing adequate household waste disposal in fringe-area developments.

Since this fringe area sewerage problem has been expressed as most serious by many State Sanitary Engineers, this paper will deal with the solution in several areas.

To the home-building industry, as the State Sanitary Engineer, the control and disposal of household wastes has become a problem of major concern. The Construction Department and Research Institute of the National Association of Home Builders has been aware for some time that the problem is

becoming increasingly acute. The need to present cost and construction data
derived from the actual experience of several fringe-area developers led to a
cooperative study conducted by the Public Health Service and the Association.
Twelve States, covering several geographic regions of the country, were in-
cluded in this survey. In each of these, extensive fringe-area development is
being experienced.

In the twelve-State survey, information pertaining to sixty-one subdivi-
sions was obtained. This information included data on unsatisfactory septic
tank installations, construction cost of fringe-area sewers and treatment, use
of package and conventional-type treatment plants, stage construction of
treatment facilities, operating personnel and costs, financing and revenue-
producing service charges, insuring and lending-agency appraisals, and in-
dividual State administrative policy procedures.

Since so many facets of this complex problem were studied during the
survey, complete coverage in this paper is impossible in the limited time
available today. It is hoped that the information gleaned during the study on
each area will be made available, in the near future, to those interested in
this problem, through a publication now under consideration by the Public
Health Service and the National Association of Home Builders. The success
of fringe-area community sewerage systems depends a great deal on (1) State
policy and (2) costs.

State Policy

State philosophy and feeling with respect to fringe-area sewerage systems
varies considerably as reflected by the support given most systems. Varia-
tion is evident in health departments as well as in insuring agencies. How-
ever, approval of sewerage practices by insuring agencies is generally based
on the recommendation of the health authorities.

In the State of New York, fringe-area sewerage systems are not approved
unless a written agreement has been made between the developer and the
municipality for the city to operate and maintain the system.

In Indiana, representatives of the State Board of Health consider fringe-
area sanitary sewer systems and treatment facilities a definite stop-gap
measure for solution of the septic-tank problem in these areas. Approval of
this type of facility is granted only where the system will, in the not too dis-
tant future, be integrated into or incorporated as a public system.

In Texas, the State Department of Health looks with favor on subdivision
community sewerage systems as a stop-gap measure in overcoming the
problem of individual home septic tanks in fringe areas.

In Oregon, representatives of the State Board of Health are of the opinion
that a community sewerage system serving fringe areas is the answer to the
numerous problems of the individual home septic tanks in subdivisions.

In Colorado, representatives of the State Board of Health favor construc-
tion of fringe-area sewerage systems at the time subdivisions are started.

Representatives of the Missouri Division of Health approach the problem
of sewage disposal in fringe areas as one of substantial, long-range, coopera-
tive planning between the State and county sanitary engineers, the insuring and
lending agencies, and fringe-area developers.

In New Jersey, representatives of the State Department of Health report
that the State Association of Home Builders cooperates to the fullest extent,

and most developers of subdivisions in fringe areas avoid the use of individual home septic tanks. They feel that New Jersey now has an orderly process leading toward the solution of sewerage problems in fringe areas.

Representatives of the Florida Board of Health are convinced that a sewerage facility, including the privately-owned community system, is the only practical solution to fringe-area subdivision sewerage problems. Subdivision systems are not only encouraged but are a definite requirement in Florida.

All twelve of the State Health Departments visited in the study are of the opinion that the operation and maintenance of a fringe-area sewerage system is most satisfactory if it is under the control of some government agency such as a municipality, town, water control and improvement district, or sanitary district of some sort, as may be provided in State enabling legislation. This type of governmental operation is mandatory in seven of the twelve States, although interim operation and maintenance is permitted by a developer until such time as the subdivision building is virtually complete. In five States of the twelve visited, the State regulatory agency approves private operation and maintenance of the system by the developer. In most of the States where private operation is approved, home-owners' associations may take over the operation when the subdivision developer completes construction.

Operation of sewerage systems under authority of State utility commissions is approved in six of the twelve States visitied. However, in one State the sewerage utility must be operated in conjunction with a water service.

<center>Cost</center>

The cost of a subdivision community sewerage system is a second factor important to its success. It must not be substantially greater than the aggregate cost of individual household waste disposal units for the community concerned. We have found that septic tank installations vary considerably more than threefold in cost, depending on several variables such as soil conditions, ground water level, state requirements, etc. The approximate cost is $150 in Florida; $250 in New York; $300 in Oregon and Texas; $350 in New Jersey, Illinois, and Missouri; $400 in Kansas; $500 in Indiana. Areas not included in the study will possibly have other cost figures, but most probably they will fall somewhere within the $150 to $500 range found in the survey.

Subdivisions to be developed with one hundred houses or more are considered easily adaptable to a community system, and it appears that in most areas there is little question of the economic feasibility of such a system.

Wakefield reported that for subdivision sewage collection systems with secondary treatment constructed in Florida since 1950, minimum construction contract costs were $320 a house for a subdivision of 125 houses and $161 a house for a subdivision of 1,200 houses. As stated earlier, Florida septic tank systems cost in the neighborhood of $150.

In Harris County, Texas, one developer, utilizing a metal, semi-permanent type of treatment plant in lieu of concrete, experienced a sewerage system cost of $463 per house, based on the first 80 homes connected in April 1956. The projected cost, based on the ultimate 1,000-home development, will be reduced to about $106 per house. Septic tanks would have cost around $300 each, about $163 per house less than the sewerage system cost for the first

80 homes. Ultimately, however, savings of nearly $200 per house will be realized by construction of a sewerage system for the area.

Another Texas developer who had completed 15 homes in the $35,000-and-up price range on half-acre lots, stated that it is more economical for him to provide sewers and treatment than to provide individual home septic tanks. He reported that his past experience has shown that these tanks, properly installed, cost from $485 to $525 each. This amount would not include cost of the 300 feet of drain tile field required for the specific soil condition in the area. The total cost would therefore be more than the sewerage-system cost of $635 per house to serve the 29 homes to be built in the development. The financing for this sewage collection system and semi-permanent, metal treatment facility was provided by the developer's private capital. A proportionate share of the total cost can be included in the sale price of each individual property, as all properties are sold under conventional loans and not restricted by Federal insuring agencies' appraisal values.

In 36 of the 61 fringe-area developments included in the study, all costs of the sewers and treatment works were recovered in sales based on appraisals placed on the houses by the Federal insuring or lending agencies.

In several States there were scattered cases where the developer's cost exceeded insuring agency appraisal by only a few dollars. In these scattered instances developers were of the opinion the slight monetary loss was more than offset by the enhanced sales potential of the dwelling unit.

In Kansas City and Jackson County, Missouri, permanent-type sewage treatment plants for subdivisions are not now approved. Four such plants that were constructed during the period 1950 through 1954 are now considered to have been located too high on minor watershed tributaries, with the result that treatment plant effluents flow through inhabited areas undergoing development. These subdivision plants ranged in cost from $50 to over $200 per capita.

The Missouri and Jackson County health departments have worked out a long-range plan. Relatively inexpensive temporary facilities consisting of sewage stabilization basins are being approved for the county area at the present time. These are designed for a loading of 400 persons per acre. The cost for one of these temporary basins was only $3 per capita, or about $12 per house. In Jackson county the minimum lot area requirement for individual septic tanks is 15,000 square feet, with a minimum width of 75 feet. The developer planning to build 50 or more houses may use a lot size of 7,500 square feet if he constructs a sanitary sewer system and a sewage stabilization basin.

To have a fringe area approved for building, the developer must meet the following requirements:

1. Through the county governing body he must form a Sewer District. This is accomplished by petition on his part.

2. He must obtain zoning approval for a temporary sewage stabilization basin.

3. He must, at the same time, obtain zoning permits for small lot sizes of 7,500 square feet.

4. Prior to beginning construction, he must take out permits for the first 25 houses, placing in escrow to the county $200 for each of these first permits or a total of $5,000. As he obtains each additional house permit, he must place in escrow another $200.

The funds are controlled by the county to be used in construction of inter-
cepting sewers and permanent treatment that will eventually eliminate use of
the temporary stabilization basin. These funds can also be used by the county
to construct larger sewers down the tributary watershed so that eventually
sewage from several subdivisions may discharge into a larger basin. The
county operates these basins at practically no cost for equipment, mainte-
nance, or personnel, and at no cost for power. The larger basins are still
temporary treatment facilities, which, under a master plan for construction
of permanent treatment facilities, will eventually be eliminated.

The ultimate aim is to eliminate these basins and to incorporate the areas
into the master plan. The final permanent treatment facilities are to be lo-
cated on direct tributaries to and near the Missouri River.

Planning

From a twelve State survey it appears that the trend in fringe-area
developments during the past five years, has been away from septic tanks,
and toward community sewers and treatment plants, many of them provided
by developers.

The fringe-area developers report that they depend on sanitary engineering
consultation for assistance in early-phase planning steps, and that they also
need cooperation from State regulatory agencies and the Federal insuring
agencies. Since continued mass building may be expected, in light of current
economic trends, it is important that sanitary engineers and others responsi-
ble for community environment do all that is possible to obta   mutual under-
standing and cooperation on this problem.

The sewers and treatment facilities on which data were obtained in this
study have been financed through enhanced value of the homes served by the
system and/or through monthly charges for the service. The treatment plants
range in size from facilities designed to serve as few as twenty-nine homes
to large subdivision systems planned to ultimately have ten to twelve thousand
housing units.

The economic aspects may limit the minimum size of sewerage systems
which can be built and operated independently, and frequently may limit the
extent and type of treatment which can be provided in the smaller installa-
tions. In addition, income must be adequate to meet costs of operation and
maintenance, and employment of personnel for satisfactory operation.

It therefore behooves the developer to plan sewerage systems wisely, so
that he will not find himself in financial difficulty. Information obtained from
the sixty-one areas studied in twelve States indicates that most subdivider-
developers have taken at least three steps in the early planning for their
sewerage systems.

The first step is consultation with local, municipal, or county planning
boards, with governmental regulatory agencies having control over sewerage
systems, and, in a few cases, with adjacent developers, with a view to possible
integration of the proposed system with existing or future systems.

The second step involves securing the necessary legal or regulatory ad-
vice. State enabling acts may require formation of a special sanitary or other
type of district to treat the sewage from the proposed development. If there
is no provision for such districts, all the facets of private utility, private
ownership, or Home Owners' Association regulations should be considered.

As the third step, engineering firms are retained to supply the technical advice necessary for project design. A problem confronting the developer is that of determining the possible growth rate of the project, or the rate at which the houses will be sold, in order to provide sewerage facilities that will function satisfactorily and economically at each stage of the subdivision development. In providing sewerage service to a growing fringe area, many developers have found "stage" construction of sewage treatment plants the best answer. Many of these facilities were initially designed and constructed for only a part of the homes to be built, and within a short time were expanded, perhaps by several phases, to provide capacity for the ultimate development. Installation of sewers usually just preceded the street construction and the house construction program. Such a schedule provides collection service as required, and keeps initial sewer investment to a minimum. In some States, where temporary treatment facilities are permitted, these have been so designed that they could be used later as a pumping or sewage-lift station and incorporated in an over-all master plan.

Legislation

Enabling legislation to assist in providing fringe-area sewerage facilities differs considerably throughout the country. All the States visited have laws that can be, in varying degrees, of assistance in providing fringe-area sewers. Several States reported that they need broader and more inclusive enabling legislation to provide fringe-area sewers and mandatory treatment plant operation by local government in lieu of private operation by developers.

More than one State regulatory agency, and many subdivision developers throughout the country, recommend amendment of the basic Federal Housing Legislation, so that fringe-area land improvements, including sewerage systems, can be insured as well as homes. This seems logical from the public health and sanitary engineering standpoint. As long ago as 1953 the Home Builders Association of Indiana passed a resolution pointing out the "Necessity for Insured Loans for Land Development."

Aesthetic Considerations

Although not necessarily an engineering problem, an important aspect to be considered in approval of subdivision sewerage plans is the location of the treatment facility in relation to residences or its proximity to adjacent dwelling units not a part of the immediate area development. Information obtained on this point, for our twelve-State survey, indicated that the average distance of the treatment facility from the nearest home was between four and five hundred feet. The maximum distance observed was over one mile. However, one contact aeration type treatment plant was so close to a residential rear fence that the spray device used to reduce foaming acted as an irrigation supply to the adjacent home owner's backyard. For only five of the 61 installations observed was the distance less than two hundred feet.

There is always an odor-nuisance potential, but in the installations visited in the twelve States, no noxious odors were detected during the time of the visit. Several sewage stabilization basins were observed in the Kansas City metropolitan area. These were completely free of odor from the writer's aesthetic viewpoint, and were considered to be a benefit and not a detriment—

free of even the musty or woodsy odor often detected around well-operated conventional secondary sewage treatment facilities. Such odor is not considered by most people to be objectionable.

Technical Considerations

As might be expected, the design features for the sewage treatment facilities serving 61 specific fringe-area developments in twelve States, vary in considerable degree. Fifty-seven of the plants are of the secondary-type treatment, 21 of which chlorinate the plant effluent. Two primary and two intermediate treatment plants serve the remaining four subdivisions. The effluents from both primary plants are chlorinated.

Seventeen of the plants are of the proprietary type, that is, package activated sludge, contact aeration, etc. In the use of these, the manufacturer's capacity ratings have not been completely accepted in most of the States visited, but the units are given the same complete engineering examination as for the conventional-type treatment plant.

Semi-permanent, or, as considered by some individuals, temporary-type treatment plants, have been approved in several States. In Harris County, Texas, all-metal plants of a semi-permanent nature lowered the original construction cost twenty-five to thirty percent below that of concrete structures. Many of these plants will eventually be abandoned when the Houston main sewer system is extended. In the not too far distant future, some of these developments will be a part of the city. It was reported that the use of this type of treatment facility has resulted in construction cost savings sufficient for the developer to justify economically a sewerage system in lieu of the individual household septic tank installation.

Many ingenious engineering designs have been developed for fringe-area sewage treatment facilities whereby the cost of sewage treatment has been kept to a minimum in the early phase of the housing development. Providing flexibility by building in stages, considering the future increase or addition to the degree of treatment, and/or inclusion into a master plan for the surrounding or adjacent area may be deciding factors as to the economic feasibility of fringe-area sewers. Seven State regulatory agencies of the 12 visited have approved sewage stabilization basins as interim treatment for the first houses constructed, up to possibly three or four hundred homes.

The developers who were consulted endorse subdivision sewers and treatment works on the basis of their past experience in septic tank failures. Increased costs, if any, in providing the facilities under this plan are in most instances fully compensated by higher appraisals on the houses involved.

Financing

The problem of financing sewerage facilities in fringe-areas, where the majority of home building is currently taking place, is of prime importance to the developer. If mass septic tank installations are to be prevented, this question must be considered by sanitary and local public health engineers.

SUMMARY

A major part of the fringe-area sewage disposal problem is associated with subdivision development.

During the past decade there has been an almost constant effort, and in some cases a struggle, on the part of many health agencies to find a solution to the problem of household waste disposal in this "no man's land." Some States have succeeded in restricting the use of septic tanks to widely dispersed housing, where soil characteristics assure satisfactory operation. Several States sanction use of community sewerage systems, both public and private, and encourage the construction of either type for subdivision construction in fringe-areas.

To provide sewerage for these areas outside of municipal cooperate limits is often a difficult and complex procedure. There is need for cooperative foresight, and planning on the part of city, county, and State officials, planning, zoning, and housing boards, financing and Federal insuring agencies, health departments, legislative bodies, and last but not least important, the designing sanitary engineer. It appears that the public health engineer might well assume the leadership in solving the subdivision sewerage problem. Municipal and county governments must be brought together in planning for a long-range solution to the problem.

Enabling legislation, such as that now existing in some of the States previously mentioned, is needed in many areas. In order that land developers will not be financially penalized by meeting health department requirements, some State regulatory agencies—and of course many builders—are convinced that consideration should be given to the need for Federal legislation to provide for insuring land development projects for mass building.

Journal of the
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

ADSORPTION AND ASSIMILATION IN ACTIVATED SLUDGE*

Charles Smallwood, Jr. ** A.M. ASCE
(Proc. Paper 1334)

ABSTRACT

Activated sludge is widely used for the stabilization of sewage and indus-trial wastes. Evidence is presented to show that the soluble organic matter is removed from solution by assimilation while suspended and colloidal or-ganic matter is removed by adsorption.

INTRODUCTION

Activated Sludge is a satisfactory method of purifying sewage because it: (a) transfers pollutional material from sewage to the sludge; (b) the sludge is readily separated from the sewage by sedimentation; (c) the volume of excess sludge built up during the process is small relative to the amount of sewage treated; (d) the sludge may be recirculated and used again and again.

The degree of satisfaction gained from the process is determined by a number of factors that are related both to the sludge itself and to the sewage. Among the factors related more or less to the sludge are: (a) the total quantity of sludge in the process; (b) the biological activity of the sludge as evidenced by the oxygen demanded or the carbon dioxide evolved; (c) recircu-lation of sludge; (d) and the pH. Among the factors related to the sewage are: (a) physical composition; suspended, colloidal, soluble proportions; (b) chemi-cal composition, fats, carbohydrates, proteins, inorganic salts necessary to metabolism.

Purification appears to proceed in stages. There is an initial stage, in which purification proceeds at a very high rate, being completed inside of an hour, and in which as much as 70% of the pollutional load is removed. This

stage is followed by a period of relatively slow removal of pollutional matter and in which oxygen requirement is stable and appreciably below that evidenced in the initial stage. This stage may last four hours or more and is called reactivation. There is a final stage of nitrification in which nitrates appear and a very stabilized effluent is created. Few plants allow the process to proceed to this point.

There have been many efforts to explain and formulate the reactions taking place in the various stages. Among the most recent are those of Gould,[4] Fair and Thomas[3] and Weston and Eckenfelder.[7] Gould has developed a practical theory of sludge age which permits the effective operation of overloaded sewage treatment plants. Thomas has worked more along mathematical lines to develop a theory explaining operational results. Eckenfelder has worked along biochemical lines, proposing chemical reactions to explain various stages of the activated sludge process. In general the theories compliment rather than negate each other. Of particular interest to the studies reported here are the phenomenological bases of the Gould interpretation of the process. Mr. Gould reports that during the initial stage of the purification process the sludge removes a large proportion of the total pollutional load from the sewage. If the sludge is separated from the sewage immediately, it is found to retain a high fraction of its purification power, and may be immediately recirculated. The purification amounts to perhaps 60 or 70% and the time required is only one or two hours. If instead of removing the sludge after this initial period, aeration is continued the sludge becomes bulky, i.e. it occupies much more space relative to its weight. The purification achieved is better than during the initial stage, but is of little practical value for the sludge may not be efficiently separated from the sewage. Continued aeration, for a total of perhaps six hours, brings the sludge back to its original settling properties, along with a high degree of purification and a small sludge volume.

It has been suggested by numerous authorities that the initial purification is due to adsorption, since there is not time available for reconstitution and synthesis of the more complex substances of sewage into new sludge. The data available, however, do not preclude the possibility of enzymic action and assimilation. The phenomena upon which the Gould theory is based suggests that there is a very definite change in the agglutination properties of the sludge micro-organisms after the first hour of aeration.

Initial studies[8] under this contract were directed at determining the ion exchange capacity of activated sludge, since it is reasonable to assume that agglutination is related to the ion-exchange properties. It was found that activated sludge had a very small ion-exchange capacity of the order of 1 milli-equivalent per 100 grams of dried sludge for many inorganic cations. It was further found that exchange capacity varied during the progress of the purification, reaching a maximum during the first hour. High concentrations of inorganic salts were found to have only a slight effect on the purification.

In experiments designed to determine whether the ion-exchange properties were significant in the removal of organic substances there were two findings. The first was that organic substances, did not displace cations from the sludge. In the second, the addition of large concentrations of cations shortly after purification began had the effect of displacing small quantities of organic material from the sludge, but the overall purification after six hours of aeration was not affected.

Perhaps the phenomena observed in the activated sludge process should be viewed in the light of current ideas as to the nature of the surface of bacteria.

Pirie[6] has examined the evidence and concluded that what is called the bacterial surface is actually composed of as many as four layers. The outside layer is composed of an ion atmosphere which has the ion-exchange properties discussed in the report of October 1953 and confirmed by the studies described in that report. Pirie concludes that this ion layer must be very significant in determining which particles or substances penetrate to the inner layers. He further concludes that it is this layer which is important in determining the agglutination properties of bacteria. As pointed out in the earlier report, the settling properties of sludge, which are a reflection of these properties are indeed improved by the addition of large concentrations of inorganic cations, an effect which may be ascribed to the reduction of the zeta potential which appears to exist at the surface of most microorganisms.

Inside of the ion layer there is frequently a capsule. The capsule may or may not be present, and it is not essential to the existence of the organism. It is apparently secreted as a waste product of the cell under certain environmental circumstances, and while being a very viscous material, dissolves at a continuous rate into the surrounding medium. Thus the amount that is present at a given time depends on the rate of secretion, and the rate of dissolution into the medium.

Within the capsule layer is still another layer, apparently composed of lipid materials which are essential to the existence of the cell. They appear to control the flow of materials through the cell and only materials that are soluble in this layer gain ultimate admittance.

Within this lipid layer is still another layer that gives the cell, structure and form. It is a relatively rigid membrane and is held to be responsible for controlling the flow of inorganic ions across the membrane.

It may be fairly concluded that since activated sludge is simply an enormous culture of bacteria, that the same structures are present and perform the same functions. It is also clear[8] that no single mechanism can account for all the phenomena observed in the activated sludge process. Nor is it reasonable in light of the physical composition of sewage to expect that a single mechanism can be responsible for removal of soluble organic matter, of suspended matter, and of suspended matter that is of colloidal nature.

In the earlier report[8] it was pointed out that the controlling mechanism in the removal of soluble materials in sewage might be simple diffusion, selective solubility in the lipid layer, or adsorption. It was proposed at that time that the utilization of selective poisoning techniques might resolve the question of whether selective solubility, diffusion and assimilation, or simple adsorption was responsible for the rapid removal of soluble materials. Studies of this type were conducted and are discussed in this report.

It does not seem reasonable to ascribe the removal of colloidal and suspended particles to a process of diffusion and assimilation, but it is very difficult to prove that it does not happen this way. The advent of radioactive tracers has provided a powerful tool for research of this type. By tracing the path of a suitable radio tracer it should be possible to determine what is being metabolised in the activated sludge process, and when. Studies using this technique are also described and discussed in this report.

Principles and Procedures

Two studies are described in this report, both dealing with the question of whether organic material removed from sewage is adsorbed, or whether the

controlling mechanism is actually some other mechanisms such as assimilation.

The first study deals with the fate of soluble organic material. The technique employed was that of selective poisoning.

The second study deals with the fate of complex colloidal organic material. The technique employed was that of tracing the metabolism of a colloidal material tagged with radio-active carbon.

Soluble Organic Matter

Principle: In the selective poisoning technique, a poison which is known to inhibit assimilation processes was employed. The agent was sodium azide which is known[2] to block assimilation processes but to stimulate oxidation when used at very low concentrations.

If the removal of soluble organic matter proceeds by a process of simple adsorption, then measurements of the organic matter removed, as indicated by reduction of the 5-day BOD test, and the build up of suspended solids in the mixed liquor should proceed in the presence of the poison. If, however, the removal is accomplished by a process of assimilation, then the reduction of the 5-day BOD should proceed normally, and there should be no build-up of suspended solids, and there may be an actual reduction of suspended solids due to oxidation of materials previously assimilated. In Fig. 1 below it is seen that the soluble organic matter may be either oxidized or assimilated. The assimilated material may in turn be oxidized if the processes of synthesis are blocked. As pointed out, sodium azide is known to block reaction "A" and to stimulate reactions "B" and "C."

```
                                              Intracellular assimilated matter
                                  A
                                                        |
Soluble organic matter <                                B
                                  C                     |
                                                        Y
                                              Metabolic end products(CO2 etc.)
```
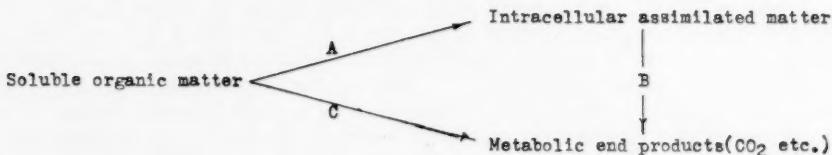
Figure 1

Procedure: Two glass cylinders holding approximately 1500 ml. were charged with 1000 ml of a mixture of activated sludge and a synthetic sewage containing either nutrient broth or glucose, and aerated for varying periods of time. One cylinder was maintained as a control, while the other cylinder was made 0.01 M with sodium azide. At appropriate time intervals, measurements were made of the suspended solids concentration, and the 5-day BOD, in each cylinder. All measurements were made in accordance with the procedures established and published by the Federation of Sewage and Industrial Wastes Associations in "Standard Methods for the Analysis of Water, Sewage, and Industrial Wastes," 10th Edition.

Colloidal Organic Matter

Principle: It is well known that complex organic materials are removed from sewage by activated sludge. Whether the removal is by simple adsorption, or whether there is a rapid enzymatic breakdown of the complex material and a subsequent assimilation is difficult to prove with the data and

observations available. The availability of organic materials tagged with
radio-active isotopes has provided a means of tracing the metabolism of such
complex materials. The material employed in the experiments performed in
this study was the algae "Chlorella." The algae is grown in an atmosphere of
radioactive carbon dioxide, $C^{14} O_2$ and thus is uniformly tagged with C^{14}. If
such complex organic material is actively metabolised by activated sludge
then the carbon dioxide evolved will contain the radio-active C^{14} which is
measureable by appropriate counting techniques. Moreover the rate at which
the carbon dioxide is given off is measureable, and so a measure of the rate
at which the complex materials are metabolised is available.

Procedure: Air is drawn through the following chain:

1) A gas absorption bottle containing 3N NaOH to remove carbon dioxide
   from the air.

2) An Absorption bottle filled with activated alumina to reduce the moisture
   in the air and prevent the carry over of NaOH into the reaction vessel.

3) A reaction vessel consisting of a 250 ml separatory funnel equipped
   with a gas diffusion tube. The mixture of activated sludge and syn-
   thetic sewage is contained in this vessel followed by a dry trap to pre-
   vent carry-over to the next absorber.

4) A gas absorption bottle containing a measured volume (150ml) of car-
   bonate-free sodium hydroxide in which the carbon dioxide evolved from
   the sludge sewage mixture in the reaction vessel is absorbed.

5) A gas absorption tube to collect any carbon dioxide not captured in (4).

6) A dry trap to prevent carry-over to the vacuum pump.

7) Vacuum pump to pull air through the train.

The reaction train was set up in a hood and the exhaust of the vacuum
pump was discharged into the hood. This was a precautionary device, for
even though only 0.1 micro-curie of carbon-14 was used in any one experi-
ment, it was not desired to discharge this into the atmosphere of the labora-
tory.

The freeze dried algae were suspended in distilled water and sufficient to
yield approximately 0.1 microcurie was added to 150 ml of mixed sewage and
activated sludge in the reaction vessel. The mixture was aerated.

At appropriate intervals, aliquots of the sodium hydroxide in the gas ab-
sorption bottle were removed. The carbonate absorbed was precipitated by
adding an excess of barium chloride in the presence of a volume of
1N NH_4Cl equivalent to the amount of sodium hydroxide taken. The purpose
of the ammonium chloride was to prevent the co-precipitation of barium
hydroxide. The precipitate is allowed to sit for fifteen to twenty minutes,
and then filtered through #40 Whatman filter paper of approximately (2.54)
sq. centimeters. The sample is dried at 103^oC for one hour then weighed,
and counted.

Counting was accomplished in a D46A gas flow counter (Nuclear), with a
Model 165 Scalar (Nuclear).

Activated Sludge

The sludge employed in these experiments was built up by aerating a weak domestic sewage obtained from the Raleigh Sewerage system. The sewage had the following characteristics:

pH   7.5

5-day BOD   250 ppm

Effluent BOD after 24 hours aeration   less than 65 ppm

Total Solids   517 ppm

Total Suspended Solids   178 ppm

Total Dissolved Solids   339 ppm

Total Volatile Solids   184 ppm

Volatile Suspended Solids   173 ppm

To determine the fraction of the 5-day BOD which was due to the colloidal and soluble fractions, a sample of settled sewage was filtered through a millipore membrane. The results of this experiment:

Raw Sewage   250 ppm   5-day BOD

Settled Sewage   174 ppm

Filtered Sewage   148 ppm

Thus the soluble portion contributed 5% of the 5-day BOD, the colloidal fraction 10.4%, and the settleable solids 30.6% of the total 5-day BOD.

In addition to the natural sewage employed to build up the sludge, a synthetic sewage was employed to maintain it under reproducible conditions. The synthetic sewage had the following composition:

Peptone	0.3	gm/l
Meat Extract	0.2	gm/l
Urea	0.05	gm/l
Na_2HPO_4	0.05	gm/l
NaCl	0.015	gm/l
KCl	0.007	gm/l
$CaCl_2$	0.007	gm/l
$MgSO_4$	0.005	gm/l
Cellulose	0.075	gm/l (Toilet paper)

It is interesting to point out, that originally the synthetic sewage had a distinct color which was reduced by aeration, but not entirely removed. In an attempt to improve the sewage, cellulose, as derived from an institutional brand of toilet paper, was added in the proportions indicated. The addition of the paper, resulted in a sewage which yielded a sparkling clear effluent after 24 hours aeration. The paper had no measurable 5-day BOD.

To determine the 5-day BOD of the various nutrients employed in these experiments a series of determination were made on both millipore filtered and non-filtered samples. The results of these determinations are listed below:

Table I

5-Day BOD of Complex Organic Nutrients

Substance	Amount mg/l	5-Day BOD Calculated	5-Day BOD Observed
Soluble Starch	500	405 ppm	92 ppm
Soluble Starch (filtered)	500	405 ppm	0 ppm
Proteose peptone	500	350	315
Nutrient broth	500	280	314
Nutrient broth (filtered)	500	280	290
Toilet Paper	500	405	0

It is apparent that for both proteose peptone and nutrient broth the results are substantially in agreement with theory. It should be noted that both of these materials, though complex in structure, are soluble materials and must not be considered as colloids. In the case of starch, quite a different result is obtained. It is apparent that starch though classified as a partly soluble material, is a true colloid.

Parenthetically, it should be remarked that the low 5-day BOD of a typically colloidal substrate raises interesting problems in the field of stream sanitation. Thus the standard 5-Day BOD determination would be extremely unreliable in determining the actual oxygen demand of a stream.

Results

Soluble Organic Matter

Typical results from experiments demonstrating the effects of azide on the assimilation of nutrient broth and glucose are shown in Tables II and III.

Colloidal Organic Matter

A preliminary experiment was performed to determine whether there was any carry-over of radioactive C-14 in the air flow. A small quantity of the chlorella suspension, 0.1 ml, 0.1 micro-curie was added to 100 ml of distilled water and aerated for one hour. The activity of the sodium hydroxide in the absorption tubes was measured at the beginning and at the end of this period. It was found that there was no change in the activity of the sodium hydroxide, that no carbon dioxide was carried over. It was concluded that there would be no carry-over of carbon-14, except that released by metabolism of that chlorella which is added to the mixed liquor.

Typical results from experiments demonstrating the metabolism of complex organic matter (as typified by the algae Chlorella) by activated sludge are shown in Tables IV and V.

Discussion

The fact that purification of sewage by activated sludge proceeds at a very high rate during the initial stage of the process has been taken as more or less conclusive evidence that the purification is by adsorption. The conclusion does not take into account the fact that organic material in sewage may occur in different physical as well as different chemical states, and should be examined more carefully in light of the physical and chemical state of the organic material to be removed.

In the case of soluble organic matter, it is possible that removal is by a process of assimilation, and evidence has been presented here that such is the case. Two nutrients, glucose, very simple in structure, and nutrient broth, very complex in structure were employed to demonstrate that in the presence of sodium azide, a poison which inhibits the assimilation process, that no assimilation takes place. Purification proceeds in the presence of the azide, but there is no increase in the amount of sludge solids. If adsorption were the significant mechanism in the purification process, the azide should make no difference in the build up of sludge solids. Since it was observed, however, that there was no build up in sludge solids in the presence

Table II

Effect of Sodium Azide on the Assimilation of Nutrient Broth

Exp. No.	5 Day BOD Initial	Final	Suspended Solids Initial	Final	pH Initial	Final	Sludge Volume Index Initial	Final
1 Control	No Nutrient		2091	2003				
1 Azide	No Nutrient		2091	1604				
2 Control	308	70	2510	2013				
2 Azide	308	99	2510	1974				
3 Control	308	80	3000	3314	6.2	7.2	50	41
3 Azide	308	56	3000	2809	6.2	8.2	50	46
4 Control	308	118	2012	2125	8.0	7.1	61	56.5
4 Azide	308	72	2012	1985	8.0	8.2	61	62
5 Control	308	164*	3162	3240	8.0	7.4	68	58.5
5 Azide	308	164*	3162	3178	8.0	8.0	68	60

Table III

Effect of Sodium Azide on the Assimilation of Glucose by Activated Sludge

Exp. No.	5-Day BOD Initial	Final	Suspended Solids Initial	Final
1 Control	0	0	2992	2645
1 Azide	0	0	1970	2040
2 Control	370	0	2288	2352
2 Azide	370	1	2296	2300

Table IV

Typical Results: Metabolism of Complex Organic Material by Activated Sludge in 6 Hours

Metabolism of C-14 tagged Chlorella by Activated Sludge

SS conc.= 971 ppm

Time Hours	CO_2 Evolution mg/gm/hr	Activity of M.L. c.p.m.	Activity of NaOH c.p.m.	%Chlorella Metabolised
0	0	38,480	0	0
1	85	17,990	2,120	5.5
4	76	17,630	5,380	14.0
6	99	15,560*	5,550	14.4

* The activity after 6 hours aeration, was distributed 40.6% in the supernatant and 59.4% in the activated sludge.

Table V

Typical Results: Metabolism of Complex Organic Material by Activated Sludge in 18 Hours

Metabolism of C-14 tagged Chlorella by Activated Sludge
Suspended Solids Concentration 543 ppm

Time Hours	CO_2 Evolution mg/gm/hr	Activity of M.L. c.p.m.	Activity of NaOH c.p.m.	%Chlorella Metabolised
0	0	10,750	0	0
1	202	10,530	330	3.1
6	204	8,300	2,270	21.1
18	204	9,160	—	< 22%

of azide, whether the nutrient was glucose or nutrient broth, we must con-
sider the data as evidence that soluble nutrients, at least, are removed by
the mechanism of assimilation.

Azide is also known to stimulate oxidation of both intracellular and extra
cellular substrates. Since in most cases it was observed that there was no
significant difference in the degree of purification, we must infer that in
those cases where azide was present, purification was accomplished by
oxidation.

It is also very interesting to note that, in controls where no nutrient at all
was added, it was generally observed that samples with azide present showed
markedly greater decrease in suspended solids than did the samples with no
azide. It might be fairly taken, that there is a storage reservoir of nutrient
substrate present within the cells of the activated sludge, and that during
periods of starvation this reservoir is utilized.

In the case of complex organic matter that is in the colloidal or particu-
late state the problem is much more difficult to solve. It is clear that such
materials are removed by the activated sludge process, but it has also been
demonstrated by biochemists that such materials are not rapidly broken
down and assimilated. In order to obtain some concept of the means by
which these materials are removed from sewage and the rate at which they
are metabolised, a complex organic material in the form of the algae
Chlorella was employed. The algae had been grown in an atmosphere of
radioactive carbon $(C-14)$ dioxide, and thus uniformly tagged with $C-14$. A
very small amount of this algae was added to an actively metabolising sludge.
The sludge evolved carbon dioxide at the rate of approximately 200 mg/gm/
hour. A normal rate of evolution for very active sludge is approximately
100 mg/gm/hr with a rate of approximately 20-30 mg/gm/hr during the
reactivation stage.

The soft radiation of carbon-14 makes it ideal for studies of this type.
Few precautions need be taken since the quantities involved are so very
minute. The apparatus, however, was set up in a hood, so that no active
carbon dioxide could escape into the laboratory. There are difficulties in
measuring the carbon-14 accurately. Errors are introduced by adsorption
on glass, and self absorption of the radiation in barium carbonate precipi-
tates that were prepared for counting. In addition carbon-14 must be counted
for rather long periods of time, in order to reduce counting errors.

The results clearly indicate that the metabolism of complex materials in
the colloidal state may be very slow. After eighteen hours, the amount of
carbon-14 which appeared as carbon dioxide (metabolic end products) was
less than 20%. And in the first hour of aeration around 5%. The data suggest
that during the first six hours of aeration, enzymic activity is breaking off
exposed carboxyl groups, but that following this stage, the breakdown of the
protein is very slow.

The results also suggest that only sixty percent of the algae was adsorbed
by the activated sludge, since 40% was still measurable in the supernatant.

CONCLUSIONS AND RECOMMENDATIONS

The specific conclusions which may be drawn from this experimental work
are as follows:

1. The significant and controlling mechanism in the removal of soluble organic substrates from sewage by the activated sludge process is assimilation and not adsorption.

2. The significant and controlling mechanism in the removal of colloidal organic substrates (as typified by the algae Chlorella) is adsorption and not assimilation. The rate of metabolism of colloidal protein substrates is very low.

The data presented here are not necessarily conclusive but they are clear evidence for the mechanisms proposed. Much additional data on rate of metabolism and or purification by the different mechanisms under widely varying conditions of operation should be obtained. The techniques of investigation that are described are new and offer great promise, however, and work may proceed very rapidly to obtain the necessary additional information required for practical application.

BIBLIOGRAPHY

1. Calvin, M., Heidelberger, Charles, Reid, James, C., Tolbert, B.M., Yankwich, Peter F., "Isotopic Carbon" Wiley (1949).

2. Clifton, D. C. "Microbial Assimilations" in "Advances in Enzymology" ed. E.F. Nord, Vol 6. (1946) Interscience.

3. Fair, G.M. and Thomas, J.A. Jr. "Concept of Interface and Loading in Submerged Aerobic Biological Sewage Treatment Systems" Institute of Sewage Purification, Annual Summer Conference, June 1950.

4. Gould, Richard H. "Sewage Aeration Practice in New York" Proceedings Separate No 307, 1953, American Society of Civil Engineers.

5. Lamanna, Carl, and Mallette, M. Frank, "Basic Bacteriology" Williams and Wilkings (1953).

6. Pirie, N.W. "Nature of the Bacterial Surface," Blackwell Scientific Publications, Oxford England (1949).

7. Weston, R.F., and Eckenfelder, W.W. "Application of Biological Treatment to Industrial Wastes," Sewage and Industrial Wastes 27, 7, 802, (1955)

8. Smallwood, C. and Cote, D.N., "Exchange Capacity of Activated Sludge," Report to National Institutes of Health, October, 1953.

Journal of the

SANITARY ENGINEERING DIVISION

Proceedings of the American Society of Civil Engineers

DIRECT RECHARGE OF GROUND WATER WITH SEWAGE EFFLUENTS

R. B. Krone,[1] P. H. McGauhey,[2] M. ASCE and H. B. Gotaas,[3] M. ASCE
(Proc. Paper 1335)

SYNOPSIS

A three-year study of the technical feasibility and public health safety of injecting sewage effluents directly into underground aquifers was conducted by the Sanitary Engineering Research Laboratory under the sponsorship of the California State Water Pollution Control Board. Mixtures of settled raw sewage and water were used to recharge a 5-foot thick confined aquifer located 95 feet underground. Observations of pressure and of pollution travel were made in 23 sampling wells surrounding the recharge well.

It was found that bacterial pollutants traveled a maximum of 100 feet in the direction of normal ground water movement even though steep gradients were imposed. The maximum distance of travel was quickly reached, but intensity of pollution regressed as the aquifer face in the recharge well became increasingly clogged.

The practical recharge rate was found to be about half the safe yield of the recharge well. Periodic injection of chlorine, followed by short redevelopment of the recharge well maintained its ability to receive injected water. Gravel packing of the recharge well was found to be necessary. The results show that direct recharge of ground waters is a safe and feasible method of waste water reclamation and ground water replenishment.

INTRODUCTION

The desirability of artificially recharging underground aquifers has been evident for several years in almost every section of the United States where ground waters represent the principal source of water for domestic, agricultural, or industrial use. The most obvious method of recharge, of course, is

to accelerate the processes of infiltration and subsurface percolation by which ground waters are built up in Nature. This method has been successfully practiced on a large scale for more than 40 years by the Los Angeles County Flood Control District in a situation where seasonal floods occur on an area particularly suited to recharge by surface spreading. Successful efforts to extend the method to less suitable soils have been reported by the Soil Conservation Service and co-operating agencies,[1,2,3,4] while the California State Water Pollution Control Board and the University of California[5,6,7] have reported successful application of the method to less suitable waters, notably to the reclamation of sewage plant effluents. Geological and geographical conditions in many localities, however, especially in the vicinity of large cities where ground water overdrafts are the greatest, so limit the applicability of surface spreading that direct injection of water into porous underground strata seems the only possibility. The engineering feasibility of such direct recharge was perhaps first demonstrated at Long Island[8] where water pumped from the ground for industrial cooling purposes was successfully returned to the aquifer through recharge wells.

Prior to 1951, when the field study herein reported was begun, experiences with direct recharge at Long Island, engineering knowledge of the behavior of sand filters and theoretical considerations of the nature of porous media indicated that only clear water might be suitable for injection into water-bearing strata on a continuous basis. In California and the Southwest, however, where the need for ground water recharge is most acute, the principal available recharge waters are domestic sewage plant effluents and waste waters containing suspended and dissolved organic matter. While direct reuse of some of these waters is possible, there are many situations in which reclamation and purification of waste water can be accomplished by injecting it directly underground. Such injection must be feasible from an engineering point of view, and the underground travel of bacterial and chemical pollutants must not endanger the public health. This latter consideration has been the subject of some speculation since information in the literature was both inconclusive and conflicting. In some places illegal sewer wells brought raw sewage into contact with the ground water. Whether or not this in fact menaced the public health was a controversial matter among sanitary engineers as well as others concerned with sanitation.

In order to determine the engineering feasibility and public health safety of reclaiming sewage plant effluents by injecting them directly into ground waters, the California State Water Pollution Control Board in 1951 sponsored a field-scale investigation[9] at the Sanitary Engineering Laboratory, University of California at Berkeley.

Facilities for Investigation

In order to carry out the objectives of the investigation it was necessary to find a location at which it was possible to inject polluted water into a suitable aquifer through a central recharge well and to observe the results over an area of unpredictable extent through a system of observation wells. For economy of construction of wells the aquifer should be located at a minimum depth below the ground surface, yet deep enough that appreciable pressures could be applied without separating the aquifer or fracturing the overburden. Other desirable characteristics included limited aquifer thickness, so that its

recharge capacity might be tested with reasonable amounts of water; sound overburden; and absence of local development which might disturb pressure or flow patterns, or which might if contaminated, endanger the public health. Also, it was necessary that the well field be near to sources of settled sewage, fresh water, and electric power, as well as accessible to laboratory facilities and equipment repair shops. On the basis of logs of a few local wells, test borings were made on the grounds of the University's Engineering Field Station located on the northeast shore of San Francisco Bay. They revealed the existence of an aquifer, judged to be suitable for purpose of the investigation, at approximately 95 feet below the ground surface and some 5 feet in thickness.

The completed installation used in the investigation consisted of a recharge well and 23 observation wells, located and oriented as shown in Figure 1. The original system of wells, made during the summer of 1951, consisted of one 12-inch recharge well and 14 6-inch observation wells located along the axes designated in Figure 1 as "original East-west axis" and "original North-south axis." The left hand section of Table 1 identifies these original wells and shows their relationship to the original recharge well. It also shows the location of four additional observation wells drilled in February 1953 to extend the well field to the south and east—the direction of principal ground water movement. Such an extension was thought advisable because the first injection of sewage polluted water indicated the possibility that bacteria might ultimately travel beyond the well field limits. Failure of the original recharge well, as will be later described, resulted in a final modification of the well field in July 1953 as shown in the right hand section of Table 1.

The original recharge well and all observation wells were drilled with a standard cable-tool rig. Each observation well was cased throughout by driving a welded steel casing pre-perforated with 28 slots 1/8-inch wide by 6-inches long in a seven-foot section at the aquifer. The recharge well casing was a double-wall steel pipe, extending to a depth of 112 feet below the ground surface. A ten-foot section perforated with 920 pre-cut slots 3/16" x 1-1/2" passed through the aquifer and served as a well screen. After this recharge well proved inadequate, the final recharge well was designed to provide a complete seal between the well casing and the overburden, as well as to reduce velocities in the aquifer at its zone of contact with the well screen. It was constructed by boring a 36-inch hole to a depth of 40 feet with a rotary bit; installing a temporary casing; then continuing to a depth of 102 feet with a 22-inch rotary bit. The smaller hole was belled at minus 77 feet with a bell five feet in diameter, and a 22-inch temporary casing was installed. A 12-inch well casing such as used in the original recharge well, but with a closed bottom, was centered in the hole and surrounded with a pack of 1/2" to 3/4" pea gravel through the region of the aquifer. A 4-inch steel gravel tube was placed adjacent to the 12-inch casing, the gravel pack was sealed with sand, and the annular space around the well casing filled with concrete, introduced through a tremie, as the 22- and 26-inch casings were withdrawn. When the concrete had set, the gravel pack was increased by adding gravel while the well was being stabilized by surging with a specially designed swab and by bailing at 100 gpm for a period of 8 hours.

Figure 2 shows schematically both the ordinary and gravel packed recharge wells used in the investigation. It shows also the nature of the strata penetrated.
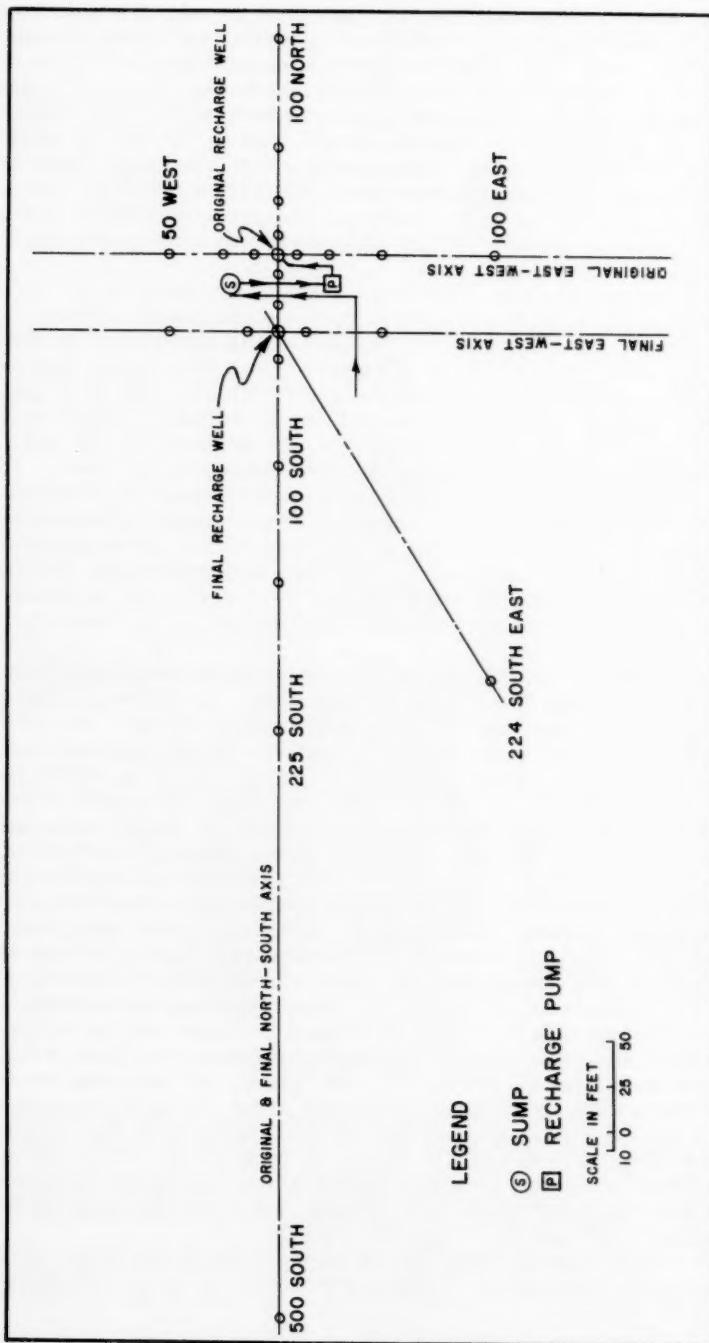
FIG. I LAYOUT OF WELL FIELD

Fig. 2. Details of Recharge Wells Used in Experimental Studies
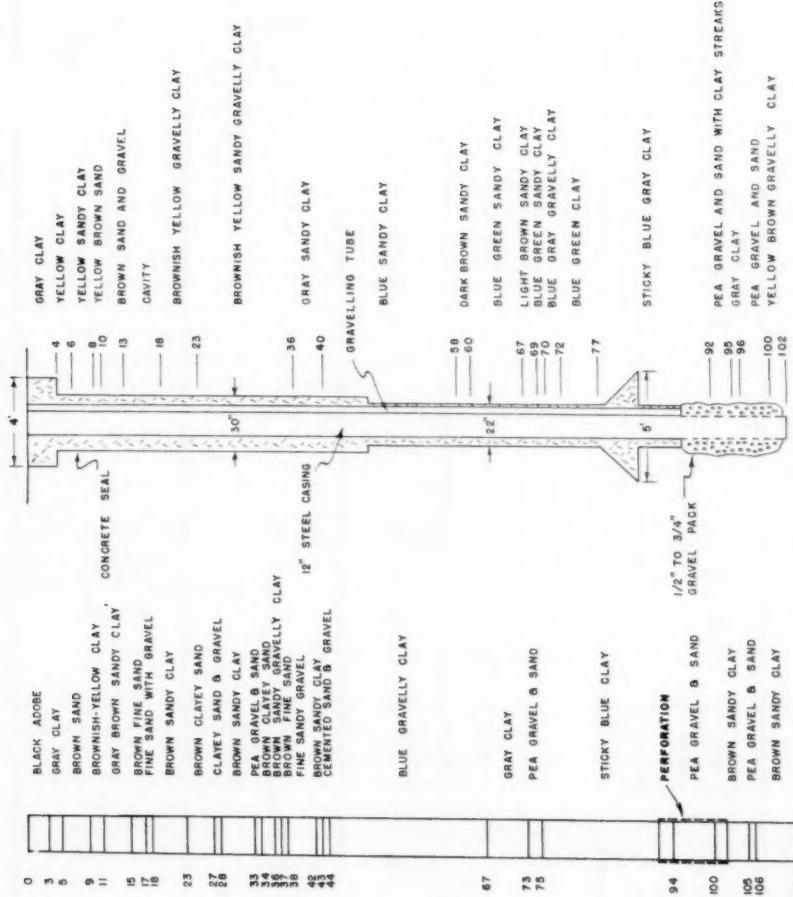
TABLE 1

Location of Observation Wells With Respect
To Original and Final Recharge Wells Used in Investigation

Original Well Field (1951)			Final Well Field (1953-54)		
Well No.	Distance from original recharge well	Direction from original recharge well	Well No.	Distance from final recharge well	Direction from final recharge well
10N	10 feet	North	25S	13 feet	North
25N	25 "	"	10S	28 "	"
50N	50 "	"	10N	48 "	"
100N	100 "	"	25N	63 "	"
10W	10 "	West	50N	88 "	"
25W	25 "	"	100N	138 "	"
50W	50 "	"	10W	39 "	N15°W
10E	10 "	East	25W	45 "	N33.7°W
25E	25 "	"	50W	63 "	N53°W
50E	50 "	"	N13W	13 "	West
*100E	100 "	"	N50W	50 "	West
10S	10 "	South	10E	39 "	N15°E
25S	25 "	"	25E	45 "	N33.7°E
50S	51 "	"	50E	63 "	N53°E
100S	100 "	"	100E	106 "	N69.5°E
*225S	225 "	"	N13E	13 "	East
*500S	500 "	"	N50E	50 "	East
*224SE	224 "	S26°30'E	50S	13 "	South
			100S	63 "	"
			N100S	100 "	"
			225S	188 "	"
			500S	463 "	"
			224SE	190 "	S31°40'E

*Added in February, 1953

Recharge well casings extended to approximately three feet above the ground surface were fitted with a flange for mounting a redevelopment pump. Fittings for pressure measurement, pressure switch, air bleed, and access were welded into the casing wall below the flange. Observation well casings were cut off close to the ground surface and equipped with 6-inch pipe caps having separate outlets for obtaining water samples and for measuring well-head pressure. The sampling outlet was made by drilling the cap and fitting a 3/16" valved copper tube which extended downward to the position of the perforated section of casing. A truck tire valve stem threaded into the well cap served as a pressure connection for either a well pot manometer or a glass piezometer tube.

The redevelopment pump was a four-stage deep well turbine with a 5-inch column, and rated at 400 gpm against a 100-foot head. It was set at minus 75 feet, with a 10-foot tail pipe and screen assembly extending below that depth. A 4" x 5" triplex positive displacement pump driven by a 20 HP electric motor through a 5-speed truck transmission and two sets of reduction gears served as a recharge pump. With this arrangement water could be drawn from a mixing sump and injected at rates of 13.5, 17, 37, 64, or 103 gpm into the well through the column of the redevelopment pump. Figure 3 is a general view of the installation, showing recharge and redevelopment pumps, intake sump, and several typical observation well heads.

Facilities for supplying settled sewage and for mixing it with fresh water in any desired proportions are shown diagrammatically in Figure 4. The two fresh water supply wells indicated in the figure penetrate a shallow aquifer shown as occurring in the 38 to 42 foot range of the original recharge well in Figure 2. This stratum, although not well defined in the log of the gravel pack well (Figure 2), appeared in most observation wells. Subsequent pumping and recharge tests showed that it was not cross-connected with the deeper aquifer used in the investigation.

Development of Wells

Bailing at the time of construction served partially to develop the wells. Subsequent development of observation wells was done with a small (10 gpm) jet pump. All wells which showed a sluggish pressure response when the recharge well was pumped were surged with dry ice and repumped. The original recharge well was developed with the four-stage turbine at rates up to 100 gpm for periods of a few hours, and finally at 70 gpm for a period of 20 days during which the drawdown remained constant at 78 feet. During this period the well behaved in a manner common to new wells, yielding muddy water at first, then clearing up and remaining clear during an extended period of pumping. Nevertheless, it was later concluded that the well was damaged during development, hence the final (gravel packed) recharge well was developed more cautiously by pumping at a rate slowly increased from 35 to 60 gpm.

Nature of Aquifer and Overburden

The aquifer recharged during the investigation is a water deposited stratum of sand and pea gravel varying in thickness from three to seven feet throughout the well field and generally located between 90 and 100 feet below the
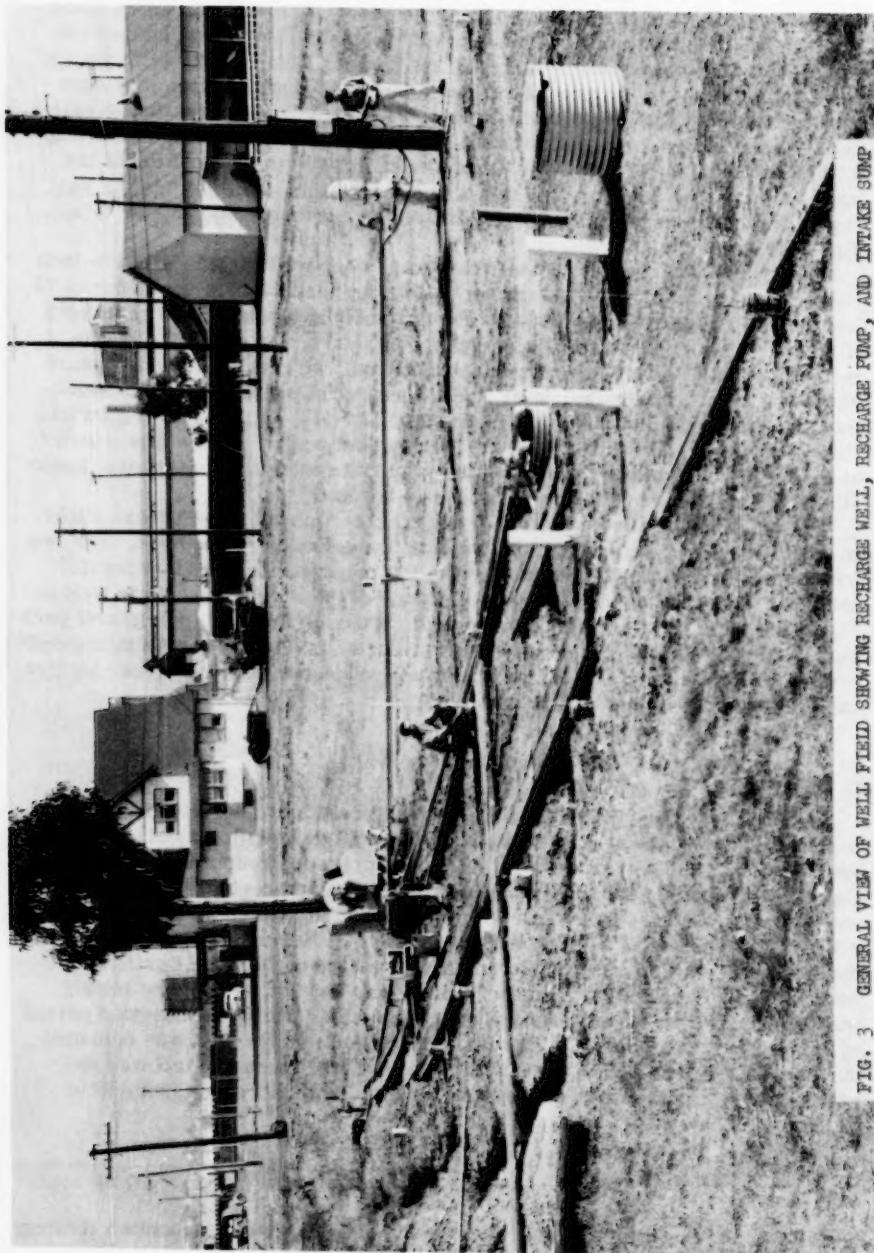
FIG. 3 GENERAL VIEW OF WELL FIELD SHOWING RECHARGE WELL, RECHARGE PUMP, AND INTAKE SUMP
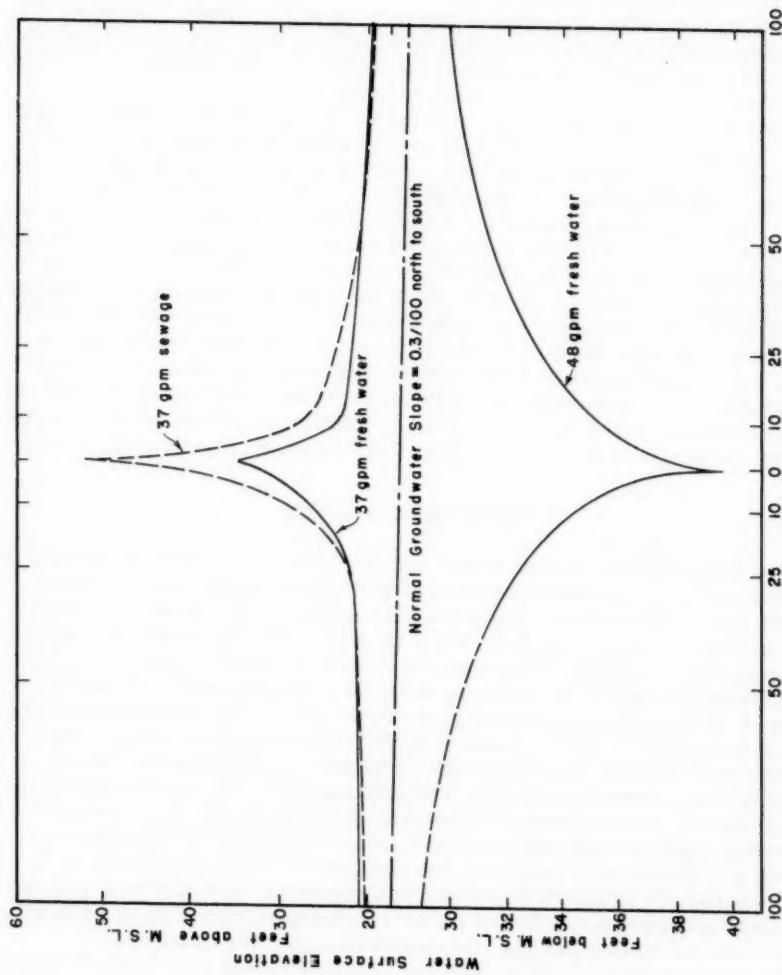
FIG. 4. TYPICAL DRAWDOWN AND RECHARGE PRESSURE CURVES

surface. Detailed observation made possible by 23 observation wells in a
small area showed evidence of non-uniformity and occasional clay lenses
with aquifer such as might be expected of water deposited strata but which
are not normally evident in the results of pumping a few wells scattered over
a large area. It is overlain and underlain by relatively impervious clay and
carries water under a piezometric pressure of about 80 feet, $\pm$ 0.5 feet. The
pressure varies because of the tides in the nearby bay. The natural pressure
gradient of the aquifer, as accurately as could be measured within the extent
of the well field, is -0.003 from north to south.

Numerous observations of particle size of the aquifer were made during
well drilling operations. Variations in findings occurred both as a result of
washing of grab samples in the bailer, and the natural non-uniformity of the
aquifer. Most commonly the effective size of material was from 0.2 to 0.3
mm., with a uniformity coefficient between 3 and 5. Transmissibility and per-
meability of the aquifer were determined graphically by applying the modified
Thiem method described by Jacob[10] to drawdown pressure distributions ob-
served during pumping of recharge wells, to recharge pressure distributions
observed during pumping of recharge wells, and to recharge pressure distri-
butions around these wells. Rough checks were obtained in the laboratory
from washed grab samples taken from the bailer during construction of vari-
ous wells. Some variability of results occurred but it was concluded that the
transmissibility of the aquifer is of the order of 8500 gallons per foot per day,
and its permeability is approximately 1900 gallons per square foot per day.

Recharge with Fresh Water

The first recharge studies were conducted with fresh water to demonstrate
the feasibility of continuous injection of high quality water, and to establish
steady state conditions as a basis for interpreting later results of recharge
with sewage effluents. For a period of 66 days fresh water was recharged in-
to the aquifer at 17 gpm (about 3 gal./min./foot of aquifer) without difficulty
and without increasing the recharge wellhead pressure above a steady state
value of 15 feet above the normal piezometric level. The recharge rate was
then increased to 37 gpm (8.4 gal./min./ft.) and fresh water injected for
periods up to 33 days at a steady state pressure of approximately 31 feet
above normal piezometric height. Observations at 3, 3.8, and 8.4 gal./min./
foot of aquifer showed injection pressures of 15, 19, and 31 feet, respectively,
indicating that recharge rate is directly proportional to recharge pressure.
During 8-1/2 months of operation, interruptions to repair equipment or to
pump out tracers occurred from time to time and the recharge well was re-
developed at rates up to 400 gpm for periods ranging from 0.25 to 1.2 hours,
but continuous fresh water injection posed no particular problems.

Chemical analyses of the ground and recharge waters (see Table 2) show
compatability with respect to both solubility of compounds and possible dis-
persion of clay by changes in the sodium ratio. No control was exercised
over the dissolved gas content of the injected waters except to avoid deliber-
ate aeration by turbulence at exposed surfaces.

At 37 gpm the observation well heads were under pressure which provided
flow through the sampling tubes without pumping, and flow through the sam-
pling tubes provided convenient samples without the need of sampling pumps.
A typical pressure mound developed in the well field under steady state

TABLE 2

Typical Chemical Analyses of
Ground Water and Recharge Water

	Ground Water	Recharge Water
Na	45 ppm	83
K	1.4	1.5
Ca	34	74.0
Mg	33.9	60.6
NH_4	0.0	0.4
Cl	48.2*	140.9
SO_4	0	172.0
PO_4	0.5	Trace
NO_3	5.3	10.7
HCO_3	271	248
CO_3	0	0
NO_2	T ppm	---
Fe	0	0.3
Si	21.2	---
pH	7.5	6.65
Cond.	0.6 m-mhos/cm	1.20
% $\dfrac{Na+K}{Ca+Mg+Na+K}$	30.8%	29.6%

*Varied from day to day

recharge conditions. Comparison of the injection and the drawdown curves
presented in Figure 4 shows that they are essentially mirror images of one
another.

Under steady state recharge conditions with fresh water, tracer studies
were made to establish the rate of water movement for comparison with later
observations of pollution travel. The time-concentration of tracers such as
sodium chloride, mixed chlorides, fluorescein, dextrose, and iodine 131 was
measured at observation wells in a series of tests. Sodium chloride proved
unsatisfactory because the large amount required to override the 240 ppm
chlorides already present at the time of the test, dispersed a clay fraction of
the aquifer. A precipitous rise in injection pressure occurred and serious
clogging of the aquifer was prevented only by prompt redevelopment of the
recharge well. A mixture of Na, Ca, Mg, and K chlorides in the proportion
occurring in the ground water overcame ion exchange troubles, but the heavy
concentrations needed to make a significant change in ground water chlorides
caused density currents which, even in the relatively shallow aquifer studied,
made it impossible to detect any pattern of its arrival at observation wells.

Fluorescein and dextrose proved generally satisfactory as tracers.
Figures 5 and 6 show the shape of time-concentration curves for fluorescein
at wells 25 feet from the point of injection.

These figures show that in all directions some portions of the injected
water moved faster than others, that there was no uniformity of flow rates in
various directions, and that ground water movement was more rapid to the
south and east than to the north and west directions. Analysis of conditions
in a non-homogenous aquifer which varies in thickness and which may be sub-
ject to stratification in discontinuous or lense-shaped layers, shows that in-
jected water will move along numerous routes of varying resistance. Hence
some portion will move ahead more rapidly along least resistant paths of
travel, underflowing, overflowing, and diffusing into existing ground water
while other portions move more slowly along more resistant paths. Should
such water carry pollutants, it can be expected that pollution travel might be
quite rapid along least resistant paths in comparison with the rate of radial
expansion of the mass of injected water which ultimately displaces the origi-
nal ground water around the recharge well.

Tracer data such as shown in Figures 5 and 6 may be interpreted in vari-
ous ways. Where bacterial pollution is concerned the fact of arrival of bac-
teria is more significant than the fact that a greater concentration may follow
at a later time. Consequently it was decided that the time of arrival of in-
jected water, as signaled by the first arrival of fluorescein, should be taken
as the basis for comparing the rate of movement of bacteria and the trans-
porting water; while the modal value of the time-concentration curve would
be taken as a measure of the time of arrival of the mass of injected water.

Recharge with Polluted Water

In order to investigate the rate and distance of travel of pollution, and to
study well clogging and methods of redevelopment, a mixture of fresh water
and primary settled sewage was injected into the aquifer. Mixtures contain-
ing 10, 20, or 27 percent sewage were used at various times, although the
higher concentrations   were most commonly used. They simulated a final
effluent from secondary sewage treatment in all characteristics except the
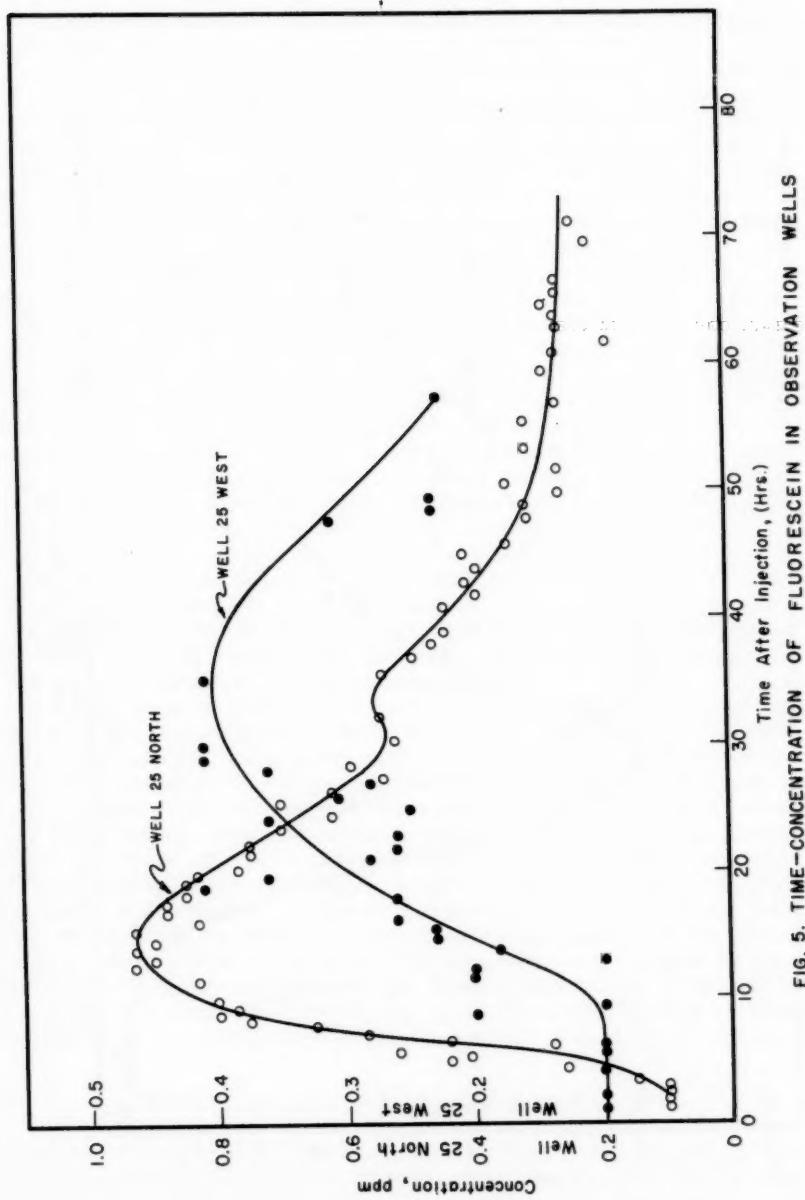
FIG. 5. TIME-CONCENTRATION OF FLUORESCEIN IN OBSERVATION WELLS
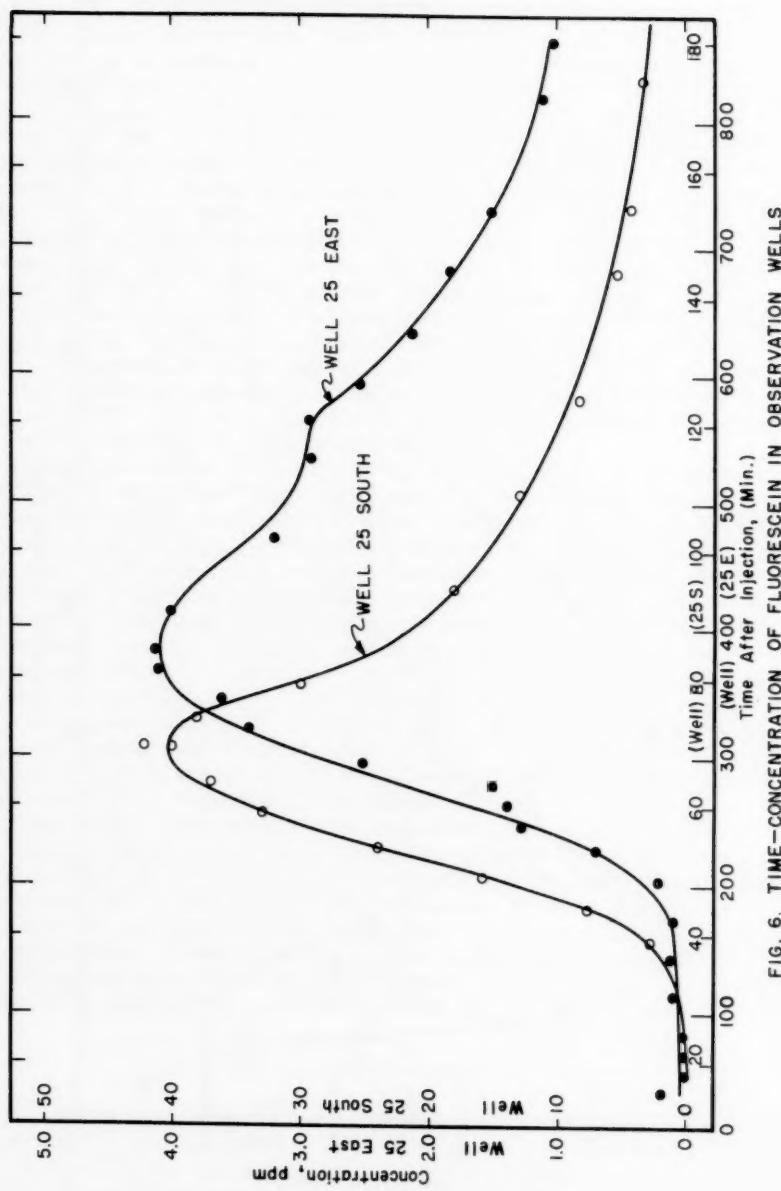
FIG. 6. TIME-CONCENTRATION OF FLUORESCEIN IN OBSERVATION WELLS

degree of stabilization of the suspended and dissolved organic matter, in which respect they imposed more severe conditions that might be expected with a final effluent. A recharge rate of 37 gpm (8.4 gal./min./ft. of aquifer), or about half of the safe yield of the well, was generally used in the investigation, although rates of 13.5, 17, and 64 gpm were used in some experiments. The technique was first to inject fresh water until a steady state pressure mound had been established; then to change over to degraded water and continue injection until the injection wellhead pressure reached a maximum acceptable limit. Inasmuch as significant danger of excessive aquifer separation was found to occur at about 75 feet of head, the acceptable limit of pressure was set at about 65 feet above normal piezometric height, or about twice the steady state pressure for fresh water recharged at 37 gpm.

With degraded water a pressure buildup began at once and proceeded at a rate directly proportional to the amount of suspended solids in the water and to the rate of recharge until excessive aquifer separation occurred. The dotted curve in Figure 4, shows that this pressure increase was confined to the area immediately adjacent to the recharge well and that pressures farther out in the well field were essentially unaffected. This means that clogging of the aquifer, as might be expected, takes place in the immediate vicinity of the recharge well. The data in Figure 4 were observed at a time when the gravel packed recharge well had been under recharge with 20 percent sewage for a period of 7 days. A number of pressure studies with fresh water indicated that the gravel pack was unsymmetrical and extended about 5 feet to the south. Furthermore, pressure patterns showed that some fracture of the aquifer extended to the sampling well 13 feet west. This minor fracture undoubtedly resulted from the drilling of observation wells close to the recharge well; a situation which would not obtain in a practical case. A shifting flow pattern was observed during recharge with sewage, indicating that early clogging of the least resistant avenues of flow took place.

The importance of gravel packing a recharge well was demonstrated soon after the start of sewage injection into the original well. After a few cycles of clogging and redevelopment the well failed by a fracture of overburden which appeared as a 14-inch hole extending to the surface adjacent to the well. Gravel packing of the well and grouting of the overburden over the adjacent area where surface springs appeared, corrected the fracture but disturbed the pressure pattern of the well so profoundly that it was judged unsuitable for controlled experimental studies. Careful analysis of all data indicated that failure of the well was progressive and developed with loss of aquifer material each time the well was pumped, ending in a fracture of the overburden after some months of operation. The well, however, furnished a great deal of valid information before the final catastrophic failure of the strata overlying the aquifer. No difficulty was encountered with the final recharge well which, as previously noted, was gravel packed at the time of construction.

Clogging and Redevelopment of the Recharge Well

During the course of the investigation, instances of well clogging by ion exchange, biological growth, and entrained gases were observed, but the most significant cause of clogging—the one to be considered in the practical case—was suspended matter and unstable dissolved organic matter capable of being precipitated by biological activity. Clogging from dispersion of a clay fraction

of the aquifer was observed during tracer studies, and never from incompatibility between recharge and ground waters. Gas binding of the aquifer was not a problem of well redevelopment.

The manner in which the pressure curve previously noted in Figure 4 developed is illustrated in Figure 7, which represents the changes in recharge wellhead pressure during injection of a mixture of 73 percent fresh water and 27 percent primary settled sewage.

Figure 7 shows that when the sewage was introduced under a steady state fresh water recharge pressure condition of about 34 feet, a pressure rise became immediately apparent. For two days this rise equaled 6.5 feet per day; then abruptly changed and continued at a fairly constant rate of 2.2 feet per day until the maximum acceptable pressure of 65 feet was approached and sewage injection was discontinued. Ordinarily the well was redeveloped at this time and the cycle repeated, but in the particular instance depicted in Figure 7 fresh water recharge was resumed in order to evaluate the effect of clogging by suspended matter.

Inasmuch as the abrupt changes in the pressure curve in Figure 7 were repeatedly observed during the investigation they are undoubtedly significant and explainable in terms of water quality. A logical explanation is that clogging of the aquifer face began as soon as suspended solids were introduced. As long as the biochemical nature of these solids was essentially constant, clogging progressed at a rapid rate, as indicated by the 6.5 ft./day rise in wellhead pressure. By the end of two days, however, a balance was established between the rate of increase of clogging due to the accumulation of raw solids at the aquifer face, and the rate of decrease in the clogging potential of solids undergoing biological decomposition. This balance then remained in effect during the remainder of the cycle. Upon the addition of fresh water, biochemical changes continued, but without the addition of fresh solids the net result was a decrease in clogging. After about 2 days the substrate approached exhaustion and the pressure became constant.

From the foregoing it is evident that for practical injection of sewage plant effluents into an aquifer, the sewage must either be clarified to a degree not commonly accomplished in sewage treatment, or the recharge well must be redeveloped. Various methods of well redevelopment were investigated during the studies. Simple pumping at any feasible rate, either with or without surging, was found to be totally ineffective in removing clogging. All successful redevelopments were accomplished with the use of chlorination. Proper combination of chlorine dosage, extent of penetration of chlorine into the aquifer, contact period, and rate of pumping was determined by trial.

In redeveloping the well it was found necessary to inject a chlorine dosage of about 250 ppm for a sufficient period to produce a residual in the sampling wells located 10 or 13 feet from the recharge well. At the injection rate of 8.4 gpm per ft. of aquifer (37 gpm) used in the investigation, the maximum time required was two hours. A contact period of about four hours was necessary, after which pumping the well at its safe yield rate of about 18 gpm per foot of aquifer (60 to 80 gpm) for two to three hours restored its original characteristics, as measured by the steady state wellhead pressure under fresh water recharge. Pumping periods as short as 20 minutes were often sufficient, while on occasion a 4-hour discharge was necessary. A maximum of 4 percent of the injected water was returned to the surface by redevelopment. During the first few minutes of pumping, this water contained large amounts of readily settleable flocculent solids. Although redevelopment water
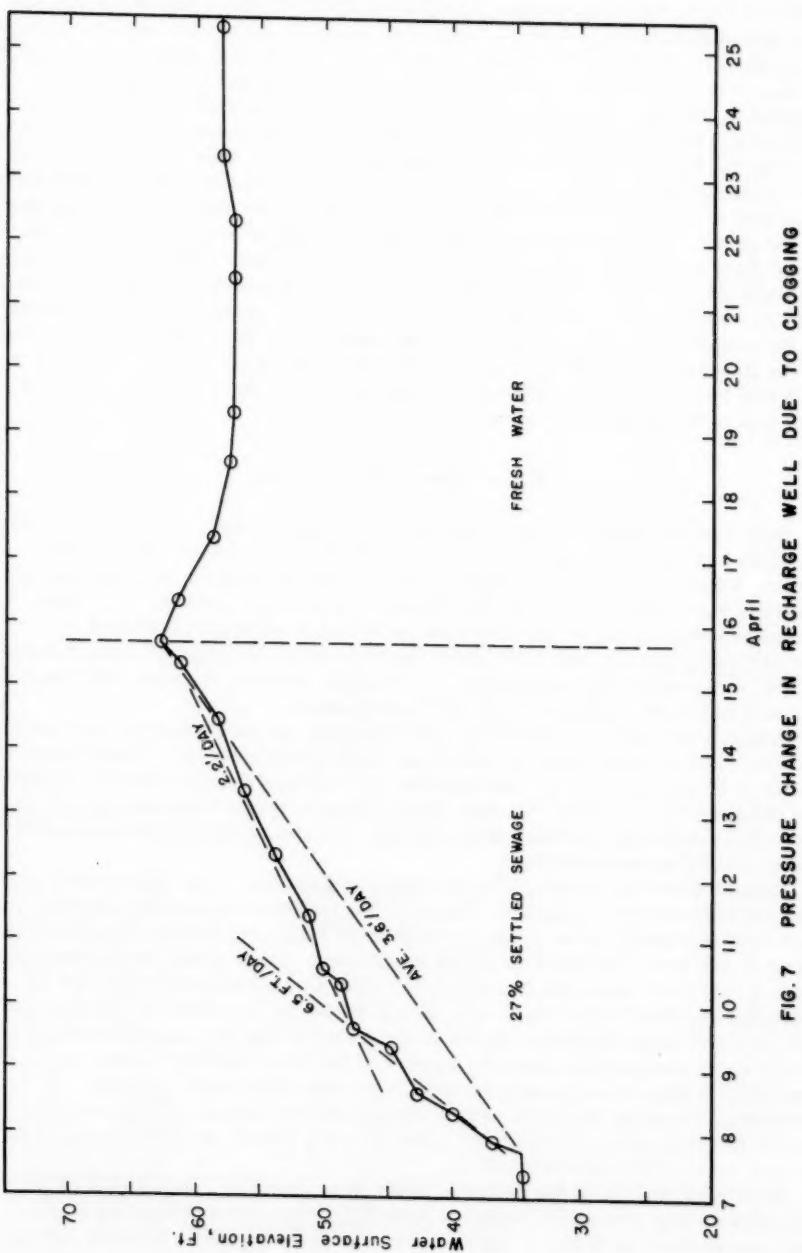
FIG. 7 PRESSURE CHANGE IN RECHARGE WELL DUE TO CLOGGING

was wasted in the experiments, it could easily have been settled and re-injected underground.

In a practical situation sampling wells would not be drilled close to the recharge well because of cost, limited utility, and danger of damage to the aquifer in its most critical pressure zone. In this case wellhead pressure drop might be used as a criterion to determine the necessary chlorine injection time. Figure 8 shows wellhead pressure changes during chlorination of the recharge well used in the Richmond, California studies. Here a pressure decrease of about 10 feet of water corresponded to the distance of penetration of the aquifer found necessary to accomplish complete well redevelopment.

A one-foot rise in wellhead pressure such as shown in Figure 8, occurring immediately after the introduction of chlorine, was repeatedly observed during the investigation. Presumably it results from a temporary consolidation of the clogging mat of organic matter as particles of the first material broken up by chlorine tend to move outward with injected water. Later, when the entire mat begins to disintegrate somewhat uniformly, the pressure rise gives way to a pressure decline.

Travel of Bacterial Pollution

Both concentration of sewage and rate of recharge were varied in a series of studies of the rate and extent of travel of bacteria with moving ground water. Degraded water containing 6, 10, 20, and 27 percent sewage was injected at rates of 3.1, 3.8, 8.4, and 14.2 gpm per foot of aquifer. Coliform organisms were used as the principal indicator of pollution, although Streptoccocus fecalis was also investigated because its physical dissimilarity to coliforms led to the speculation that it might travel a distance intermediate between coliform organisms and dissolved matter.

Comparative rates of travel of injected water, as measured by fluorescein, and of coliform organisms are shown in Table 3 for a series of experiments in which 10 percent sewage was injected at a rate of 8.4 gpm per ft. of aquifer (37 gpm) for a total of 46 days, after bacteriological examinations on 16 successive days had demonstrated that the observation wells and equipment had no coliform contamination.

Table 3 shows also that pollution travel is greatest in the direction of normal ground water flow (south). The fact that coliform organisms reached a point 100 feet south of the recharge well in 33 hours but failed to reach a distance of 200 feet in 46 days is highly significant. A uniformly expanding cylinder would have acquired a radius of 200 feet in 32 days under the rate of recharge involved in the study. From the degree of distortion of the flow pattern in a southerly direction shown in the table, it may be computed that injected water completely filled the aquifer at the well 200S for a time considerably in excess of 16 days during the 46-day observation period. Obviously, die-away bacteria cannot account for the failure of coliforms to extend 200 feet, either by the easy paths of early travel, or with the mass of moving water which arrived later.

Results of studies of the possible build up of coliform concentrations at any point during prolonged recharge with polluted water are typified by the data summarized in Table 4, which shows the Most Probable Number (MPN) of coliform organisms at various distances from the recharge well on the 3rd, 12th, and 32nd day of a 38-day period of recharge with a mixture of 10
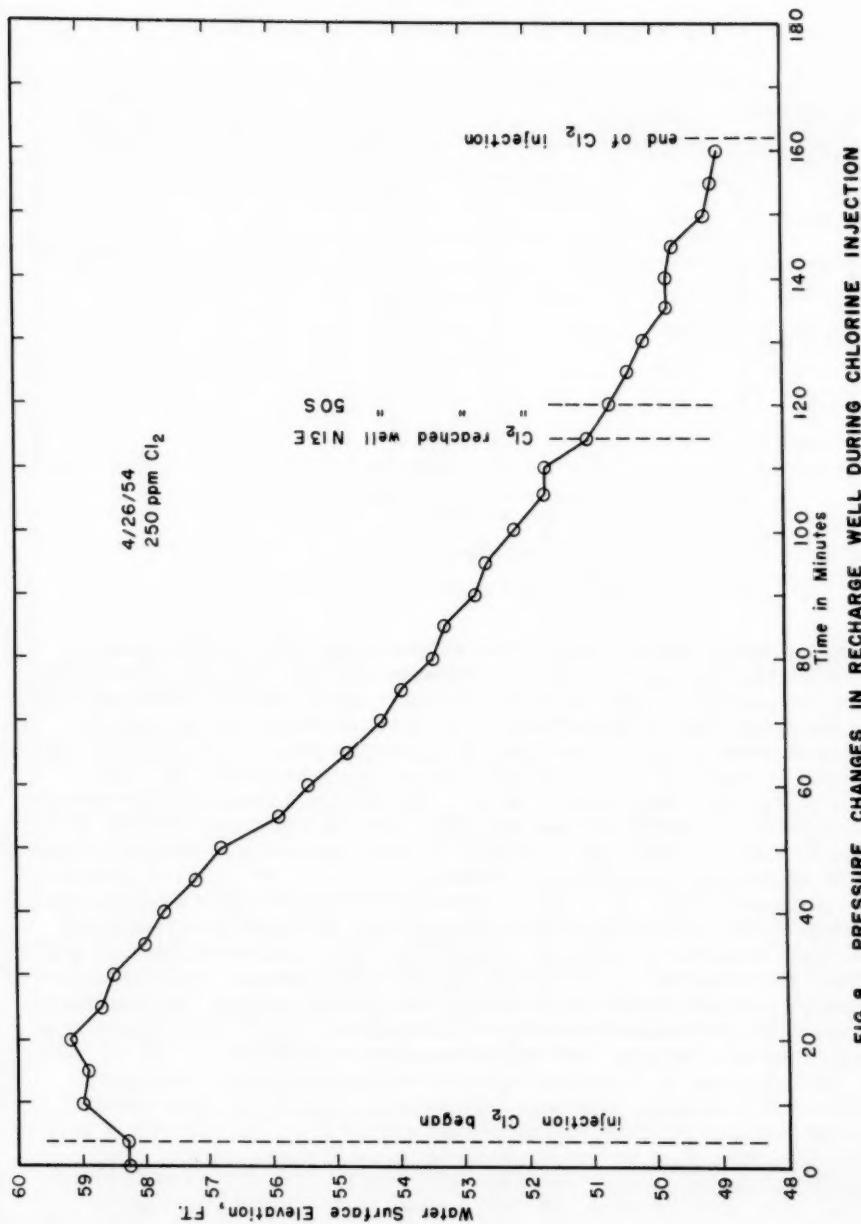
FIG. 8 PRESSURE CHANGES IN RECHARGE WELL DURING CHLORINE INJECTION

TABLE 3

Rates of Travel of Coliform Organisms and Injected Water

Distance From Recharge Well (feet)	Time of Arrival of First Injected Water, as shown by Fluorescein (hours)		Time of Arrival of First Coliform Organisms (hours)		Calculated Theoretical Time of Arrival of Mass of Injected Water (hours)
	Avg. all Directions	Max. any Direction[a]	Avg. all Directions	Max. any Direction[a]	
10	0.64	0.2	1.73	0.33	2
25	4.30	0.6	6.78[b]	0.33	12
50	12.0[c]	1.4	17.55[d]	2.1	48
100	----	15.0		30.0[e]	187
200's	----	----	---[f]	---[f]	

a Direction of normal ground water movement (S)
b Did not reach 25' west in 24 days
c No data at 50' North
d Did not reach 50' North or West in 24 days
e Reached 100' South only
f Did not reach 200' South in 46 days

percent sewage and 90 percent fresh water containing 2.4×10^6 organisms per 100 ml. Bacterial pollution was greatest near the beginning of the period and subsequently regressed as a tighter filter mat of organic matter built up at the aquifer face in the recharge well. It is notable that the most distant wells showing pollution at any time during the period were 100 feet south and 63 feet in other directions from the recharge well. Moreover, the small concentrations of organisms at these points indicate that bacterial travel in the aquifer beyond 100 feet was negligible, and the change in pollutional intensity with time shows that prolonged recharge did not cause bacteria to extend beyond their initial distance of travel.

Subsequent experiments with a mixture containing 27 percent sewage and having a coliform concentration of 4.7×10^6 per 100 ml did not produce any increase in the 63-foot distance of travel which was achieved in the first 3 days. Numerous studies with 20 percent sewage at various recharge rates during a period of more than 11 months gave similar results. The principal effect of greater amounts of sewage was merely to shorten the permissible period between recharge well redevelopments to 8 or 9 days.

Table 5 shows the maximum bacterial contamination of the well field as measured by coliform organisms, Streptococcus fecalis, and plate counts, during 7 days of recharge with 20 percent sewage at 8.4 gpm per foot of aquifer. The experiment showed no difference in the distance of travel of S. fecalis and E. coli, the maximum for both being 63 feet. Coliforms are obviously better test organism, however, because of their greater abundance.

The plate counts shown in the right hand column of Table 5 underscore the easily overlooked effects of after-contamination. Wells 100 N and 500 S show neither coliform nor S. fecalis contamination, hence it is reasonable to

TABLE 4

MPN of Coliform Organisms in Observation Wells During Continuous
Recharge with an Average of 2.4 x 10^6 Organisms per 100 ml

Distance from Recharge Well	MPN, 3rd Day	MPN, 12th Day	MPN, 32nd Day
13 Feet N	240	240,000	230
28 " N	2400	240	5
47 " N	240	38	5
63 " N	23	8.8	None
88 " N	None	None	None
138 " N	--	None	None
39 " NE	2400	240	8.8
45 " NE	None	8.8	None
63 " NE	None	38	None
106 " NE	None	None	None
39 " NW	2400	240	2300
45 " NW	240	None	5
63 " NW	None	2.2	8.8
13 " E	24,000	24,000	8.8
50 " E	240	5.0	None
13 " W	23	None	2300
50 " W	23	240	2.2
13 " S	95	2400	230
63 " S	None	None	9.4
100 " S	23	5.0	None
188 " S	None	None	None
192 " S	None	None	None

assume that other organisms likewise failed to travel with moving water.
Both of these were open wells sampled by special pumps and hence subject to
bacterial contamination from that source. The results serve to stress the
important fact that organisms already present in a well may multiply on dis-
solved nutrients injected at some other point.

Particulate organic matter which might serve as a bacterial substrate did
not penetrate the aquifer to any important extent, the smallest particles be-
having similarly to bacteria in their distance of travel. Within the biological-
ly active zone immediately surrounding the recharge well some breakdown
of solids occurs. Beyond this zone, however, adsorption represents the
principal phenomena involved in any chemical changes.

Travel of Chemical Pollution

The ion content of water in surface streams during dry weather is suffi-
cient evidence that the cations and anions normally found in ground water are
not greatly altered with distance of travel in an aquifer. Furthermore, ex-
perience in many parts of the world with such material as chlorides, picric
acid, metal plating wastes, synthetic rubber wastes, etc. shows that soluble
chemicals may move freely with ground water. It was therefore, well known

TABLE 5

Bacterial Contamination of Well Field

Well No.	Distance	M.P.N. Coliform		M.P.N. S. fecalis		Average of 3 Plate Counts
		Before Sewage Injected	Maximum During Sewage Inj.	Before Sewage Injected	Maximum During Sewage Inj.	
Recharge	0	*NC	1.5×10^6	NC	2.4×10^5	305,000
25S	13	"	240,000	2.2	24,000	3,700
10S	28	"	62,000	NC	2,400	550
10N	47	"	240	NC	38	6
25N	63	"	240	NC	38	21
50N	88	"	NC	NC	NC	44
100N	138	"	NC	NC	NC	1,100 (Open)
10E	39	"	6,200	5.0	2,400	240
25E	45	"	6.0	NC	NC	13
50E	63	"	50	NC	38	130
100E	106	"	NC	NC	NC	11
N13E	13	2.2	2,400	5.0	2,400	950
N50E	50	NC	62	NC	38	17
10W	39	NC	6,200	2.2	2,400	230
25W	45	"	700	NC	2.2	18
50W	63	"	NC	2.2	NC	20
N13W	13	"	620,000	8.8	24,000	300,000
N50W	50	"	240	5.0	38	24
50S	13	"	240,000	NC	2,400	8,300
100S	63	"	12	5.0	NC	30
N100S	100	"	6.0	5.0	NC	22
225S	188	"	NC	NC	NC	71
500S	463	"	NC	NC	NC	700 (Open)
224SE	192	"	NC	NC	NC	48

*Not contaminated

in advance that the limits of travel of chemical pollutants not subject to ion exchange with the soil, could not be explored with the well field used in the investigation. Nevertheless, hundreds of chemical analyses were made which confirmed the general belief that most ions may travel for very great distances.

Many of the ions in sewage are, of course, the same as those existing in the ground water. Hence unless industrial wastes containing toxic ions or compounds are present, the chemical quality of sewage effluents may actually be higher than that of ground water in all ions except those associated with organic decomposition, especially when sewage is derived from treated surface water.

Table 6 shows the effects of mixing 27 percent sewage from a surface water supply with 73 percent fresh water pumped from the ground in the experimental studies. Except in the case of K^+, NH_4^+, $PO_4^=$, and NO_2^-, the mineral quality of the water was slightly improved by the addition of sewage.

When mixtures of water and sewage such as shown in the table were injected underground ammonia was found to be adsorbed quickly by soil particles. Phosphates were largely associated with solids in the clogging zone near the recharge well, but those in solution seemed to travel as freely as fluorescein. There was a marked tendency for nitrites and nitrates to be robbed of oxygen in the biologically active zone of clogging of the recharge well. The amounts of these compounds, however, were never great.

TABLE 6

Analyses of Injected Waters
March, 1954

	Fresh Water	Degraded Water (27% Sewage)		
	3/5/54	3/15/54	3/17/54	3/22/54
Na^+	92.8 ppm	82.9 ppm	79.8 ppm	70.0 ppm
K^+	1.4	3.8	3.3	2.0
Ca^{++}	58.0	42.9	48.9	49.2
Mg^{++}	71.3	61.2	58.2	67.7
NH_4^+	0	5.62	5.35	0.09
Cl^-	148	136	136	136
$SO_4^=$	192	169	173	164
$PO_4^=$	3.21	13.33	7.56	1.81
NO_3^-	8.54	6.97	6.10	7.28
NO_2^-	0	3.6	1.92	0.63
HCO_3^-	242	244	244	220

SUMMARY OF RESULTS AND CONCLUSIONS

The results of the investigation support a number of significant conclu-
sions, both as to the engineering feasibility and the public health safety of
directly recharging aquifers with waste waters.

Specifically, it was found that sewage approximating the final effluent from
secondary sewage treatment in terms of suspended solids, could be success-
fully injected underground through the experimental recharge well at a rate
equal to about one-half the safe yield of the well, and that the well could be
redeveloped to restore its original characteristics after clogging had pro-
gressed to any maximum limit consistent with safety to the installation. An
injection rate (8.4 gal./min./ft. of aquifer) equal to the best reported for
fresh water recharge was found to be practical.

Gravel packing of the recharge well was found to be necessary. Clogging
occurred at or near the aquifer face and at a rate proportional to the amount
of suspended solids in the injected sewage. The effect of biochemical insta-
bility of the solids was readily observable in the pressure changes associated
with a progressive clogging. With mixtures of fresh water and 20 or 27 per-
cent primary sewage, recharge well redevelopment was necessary after 7 to
9 days of recharge. Redevelopment was accomplished by injecting chlorine,
then discharging the well at its safe yield after a suitable contact period.
About half a day was required for redevelopment and a maximum of 4 percent
of the recharged water was returned to the surface in the process. After a
brief settling period this water was suitable for re-injection underground. It
was therefore concluded that it is technically feasible to recharge ground

waters with sewage plant effluents, provided geological conditions are suitable. Furthermore, that the economics of such recharge is subject to a straightforward engineering analysis in any individual situation since only normal wells and water handling equipment are involved.

No particular danger to the public health as a result of travel of bacterial pollution with ground water moving in a continuous sand and gravel aquifer was found. Coliform concentrations of 2.4 x 10^6 per 100 ml, or greater, produced counts up to 23 organisms per 100 ml at a distance of 100 feet from the recharge well in the direction of normal movement of ground water, and at 63 feet in other directions. No coliforms appeared at greater distances, and it was concluded that bacterial travel in the aquifer beyond 100 feet from the recharge well was negligible. The initial rate of travel of coliform organisms to the maximum distance achieved by such bacteria was about one-half the rate of the transporting water. Prolonged injection did not cause bacterial pollution to extend beyond the initial distance of travel. The maximum concentration occurred soon after injection began and decreased as clogging of the recharge well developed a filter mat. Neither increased concentrations of organisms nor greater injection rates produced greater distances of bacterial travel in the aquifer.

From observations reported in the literature as well as those made in the course of the investigation, and from the very fact that ground waters are high in dissolved solids, it was concluded that the mineral quality of recharged water may be expected to undergo little improvement as it moves through an aquifer. The normal ions in sewage, however, are not pollutants in the usual sense of the word, but the fact that they move freely with ground water indicates that industrial waste waters containing undesirable materials should not be injected into the ground water.

As a result of the investigation the possibilities are increased for reclaiming sewage and other waste waters as the need for more intensive use of water becomes acute.

REFERENCES

1. Muckel, D. C., Research in Recharging Ground Water Supplies by Spreading, paper prepared for the U. S. Dept. of Agriculture, 11 pp., April, 1950.

2. Bliss, E. S., Johnson, C. E., Schiff, L., Report on Cooperative Water Spreading Study With Emphasis on Laboratory Phases. Provisional Report, Soil Conservation Service, U. S. Dept. of Agriculture, December, 1950.

3. Schiff, L., An Exploratory Study of the Effect of Surface Head on Infiltration Rates Under Water Spreading Conditions, Provisional Report presented May 7, 1952, American Geophysical Union Meeting, Washington, D. C.

4. Schiff, L., Some Developments in Water Spreading. Provisional Report, Soil Conservation Service, U. S. Dept. of Agriculture, September, 1952, Supplemented November, 1953.

5. Field Investigation of Waste Water Reclamation in Relation to Ground Water Pollution. (Report to Calif. State Water Pollution Control Board by Sanitary Engineering Research Laboratory, University of California, June 1952) State Water Pollution Control Board Publication No. 6, 1953.

6. An Investigation of Sewage Spreading of Five California Soils, Technical
    Bulletin No. 12, I.E.R. Series 37, Sanitary Engineering Research Labora-
    tory, University of California, April 1955.

7. Studies of Waste Water Reclamation and Utilization. (Report to Calif.
    State Water Pol. Control Board by University of California, Los Angeles,
    January 1954). State Water Pol. Control Board Publication No. 9, 1954.

8. Johnson, A. H., Ground Water Recharge on Long Island. American Water
    Works Assn. Jour. 40, 11, 1159-66, November 1948.

9. Final Report on Investigation of Travel of Pollution (report to Calif. State
    Water Pollution Control Board by Sanitary Engineering Research Labora-
    tory, University of California, Dec. 1954) Calif. State Water Pollution Con-
    trol Board, Publication No. 11, 1954.
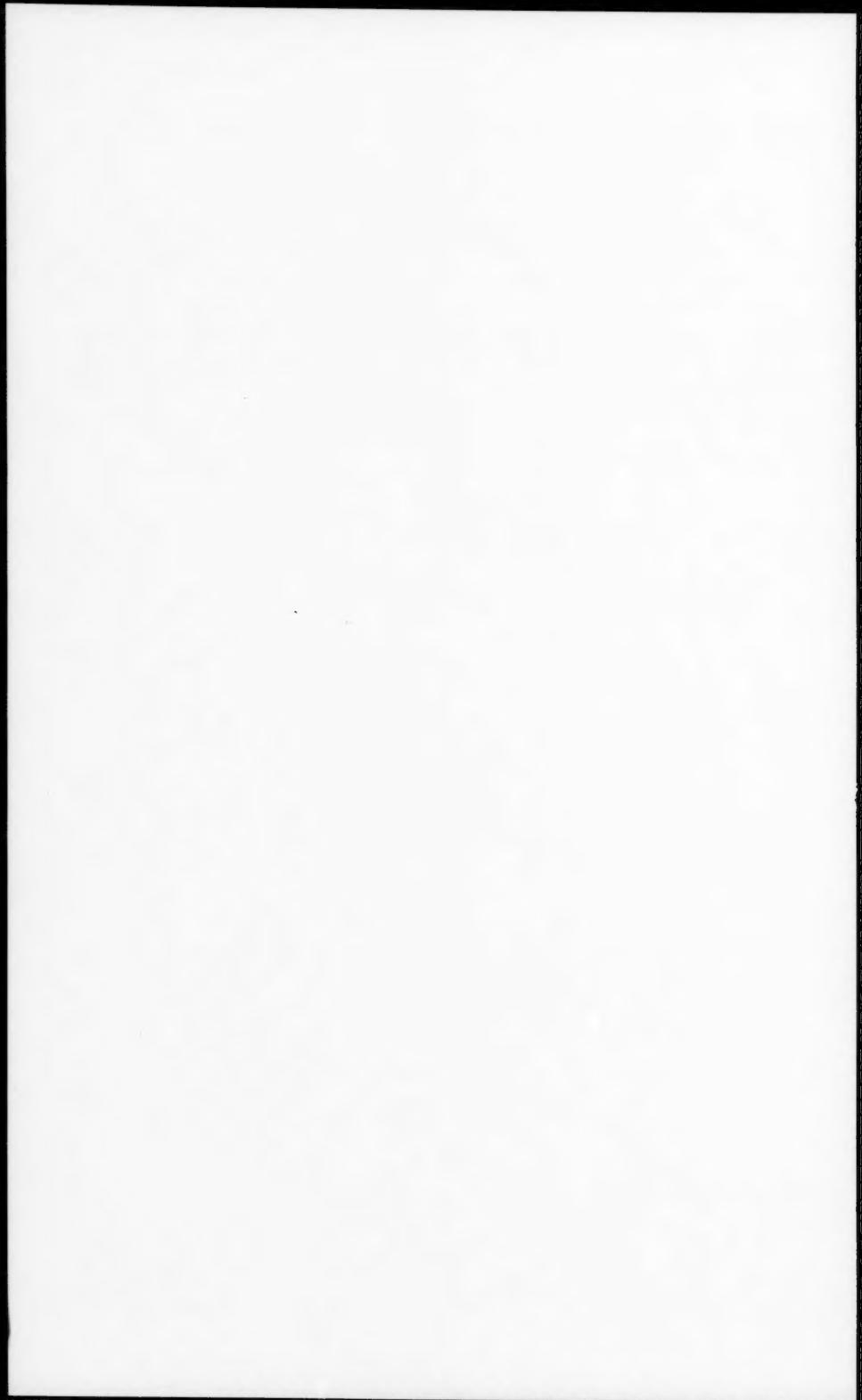
Journal of the
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

TRICKLING FILTERS SUCCESSFULLY TREAT MILK WASTES

Paul E. Morgan,* J.M. ASCE and E. Robert Baumann,** A.M. ASCE
(Proc. Paper 1336)

ABSTRACT

More data is needed by the milk industry regarding successful methods of waste treatment. This paper discusses the volume and strength of wastes discharged, and unit loadings and efficiencies at two waste treatment plants that have proved successful.

INTRODUCTION

Much information is available about the volumes and strengths of waste to be expected from various methods of milk handling and processing. Information is also available on overall removals to be expected from various types of milk waste treatment plants. In contrast, however, data pertaining to hydraulic and organic unit loadings in waste treatment plants that are and have been operating successfully is scarce.

In a literature review on milk waste treatment, no reports were found describing a successful treatment plant operation that provided complete operating data, including data on waste volumes, waste strengths, treatment plant unit loadings, and volumes of milk intake, and products produced. In order to obtain this type of information, field surveys were conducted on two treatment plants that were operating satisfactorily without creating an odor or stream pollution problem. Preliminary visits were made to over 30 representative milk waste treatment plants of all types in Iowa, Minnesota, Missouri, Illinois, Michigan, and Wisconsin. An attempt was made to locate for study a trickling filter plant, an aeration plant, and an activated sludge plant. Unfortunately, of the plants visited which could be utilized in this study, only trickling filter plants were functioning properly. Two plants were picked for detailed field study. Both plants were operating satisfactorily and

* Asst. Prof., Civ. Eng., Iowa State College, Ames, Iowa.
** Associate Prof., Civ. Eng., Iowa State College, Ames, Iowa.

were reported to have been operating satisfactorily for a number of years. The management of both plants expressed a desire to cooperate fully in the study. Both agreed to furnish complete engineering and economic data pertaining to their milk processing plant and waste treatment plant operations. One plant was a single-stage, high-rate, trickling filter plant and the other was a two-stage, high-rate, trickling filter plant. To gather representative data, two continuous 24-hour surveys were made at each plant under similar operating conditions. These surveys were made by the senior author with the assistance of other technical personnel.

In 1954, two surveys were conducted at each plant to determine operating conditions in the processing and treatment plants as they had existed for several years. As a result of observing plant operations during these surveys, waste saving operations designed to reduce the volume and strength of the milk waste produced were recommended to the management of each plant. The management agreed to adopt the recommendations, but no attempt was made by survey personnel to effect compliance with the recommendations. Later that same summer, additional surveys were conducted at each plant to determine operating conditions after partial compliance with the waste savings recommendations.

In 1955, two surveys were conducted at each plant without making any additional attempt to cut down on the volumes and strengths of the wastes produced. Then, surveys were conducted at each plant during a period when effective waste-control measures were practiced. During these periods, the survey personnel initiated and controlled the waste saving techniques proposed as a result of the in-plant studies.

Plant A Studies

Milk Handling Procedure

Since the names of the plants studied are not essential for consideration of the field tests, the plants will be referred to only as plant A and plant B. Plant A receives about 200,000 to 300,000 pounds of whole milk per day in cans direct from the producers. About 80 per cent of the milk is collected by route trucks, while the remainder is brought in by the individual farmer. The milk is dumped from the cans into a weighing vat. The weight is recorded, and the vat contents are discharged into a storage tank. From the storage tank, the milk is pumped to a pasteurizer. The cream and skim milk are separated, cooled, and stored awaiting further processing.

The cream is churned into butter, and the buttermilk is dried on a rotary drier. Approximately 10 per cent of the butter is cut and wrapped in one pound packages for local sale and the remainder is packed in 60 pound bulk boxes and shipped to Chicago. The skim milk is condensed and dried in two spray-type driers. The dried milk is packaged in barrels with plastic liners and shipped to Chicago for further processing and marketing.

During the summer months, milk is received for about ten hours a day, butter is churned for about eight hours a day, and the drying room is operated for about 20 hours a day. The treatment plant receives waste over the entire 24-hour period although the heaviest flow occurs between 6 A.M. and 12 noon.

The majority of the liquid wastes discharged to the treatment plant originate at the following sources:

1. Can dumping and draining.
2. Can washer.
3. Separator and pasteurizer drippings.
4. Cooler-cabinet drippings.
5. Churning and butter washings.
6. Leakage around pump packings, valves, and unions.
7. Miscellaneous cleanup.

Waste Treatment Plant

The treatment plant for the wastes discharged by this milk processing plant consists of the following:

1. Inlet structure and hand-cleaned bar screen.
2. Holding tank, 8,000-gallon capacity.
3. Two 100-gpm vertical, sewage pumps in a lift station.
4. A trickling filter containing 0.431 acre-feet of filter stone.
5. A final clarifier with a capacity of 5,554 gallons.
6. A sludge digester with a capacity of 2,040 cubic feet.
7. A diversion-box to circulate part of the filter effluent back to the holding tank and part to the final clarifier.

A plan view of the plant is shown in Figure 1 and some general views are shown in Figure 2.

The raw waste enters the treatment plant through the hand-cleaned bar screen and flows directly into the holding tank. From this tank, two pumps pick up the mixture of raw and recirculated sewage and discharge it to a motor-driven rotary distributor on the trickling filter. The filter effluent is split, part of it flowing into the final clarifier and the remainder returning to the holding tank. The recirculation system is arranged so that the filter will always be receiving waste from the holding tank. When the raw flow is low, the recirculated flow is high enough to maintain a constant flow to the filter. The effluent from the final clarifier flows over an outlet weir and is discharged to the municipal sanitary sewer systems.

Raw sludge is pumped six times a day from the bottom of the final clarifier to the digester. About every three months the digested sludge is hauled away in trucks and discharged onto farm lands.

Test Procedure

To determine the operating efficiency of the plant, samples of the raw sewage, filter influent, filter effluent and final effluent were collected every half hour during each 24-hour survey and composited. The raw sewage samples were proportioned by measuring the raw flow. The filter influent and effluent samples were proportioned by measuring the pump discharge. To obtain the total pump discharge, the flow leaving the plant had to be added to the amount being recirculated. To measure each of these flows, V-notch weirs were placed on the raw sewage line ahead of the bar screen, on the recirculation line, and on the final effluent line. The type of weir installed to measure the raw flow is shown in Figure 3.

The sewage flow, temperature, pH, dissolved oxygen, and physical characteristics were recorded in the field. The biochemical oxygen demand (B.O.D.), nitrogen, and solids were determined in the sanitary engineering laboratory at Iowa State College. The samples were iced during collection and transportation to the laboratory.
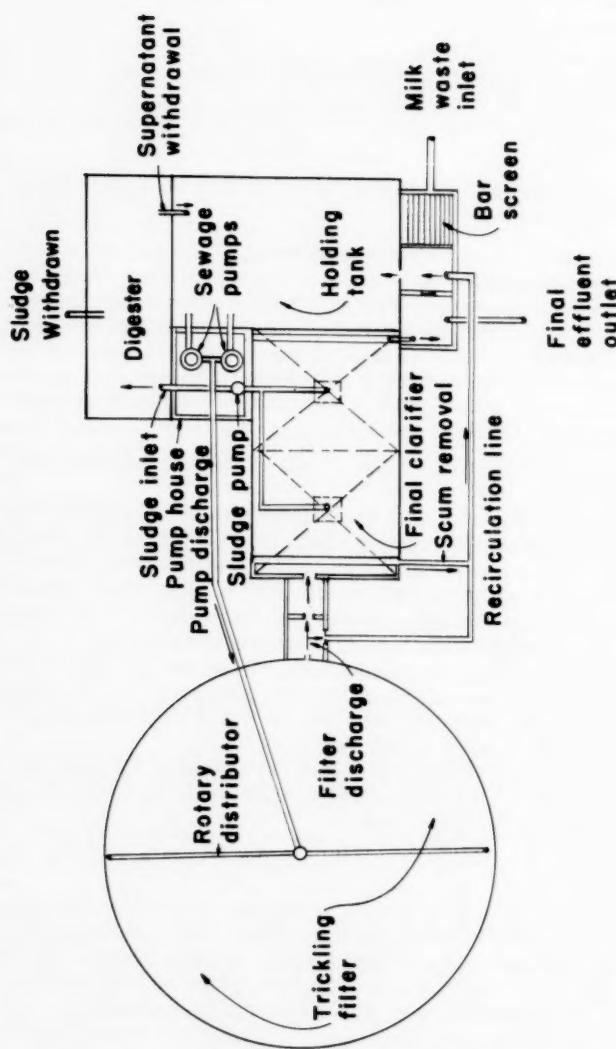
Figure 1. Schematic plan view of existing plant A.
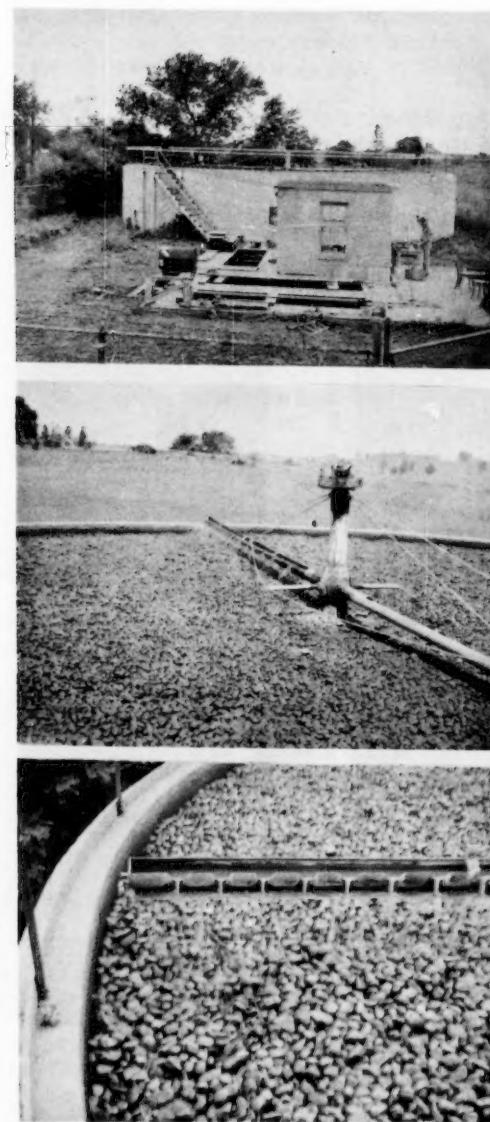
Figure 2. General views of plant A showing at top, complete plant; center, rotary distributor; and at bottom, close-up of rotary distributor discharging.

Plant B -- Recirculation and final effluent.
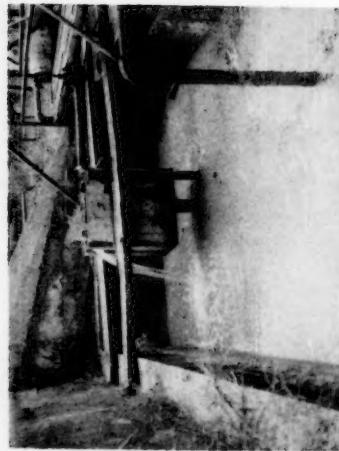
Plant B -- Raw sewage, pump discharge.
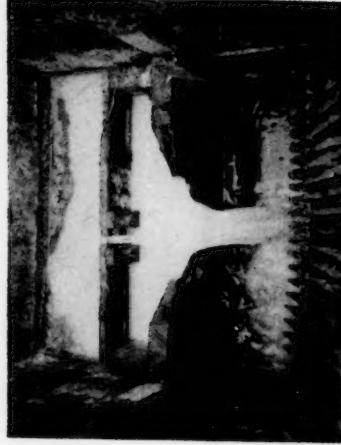
Plant A -- Raw sewage inlet.
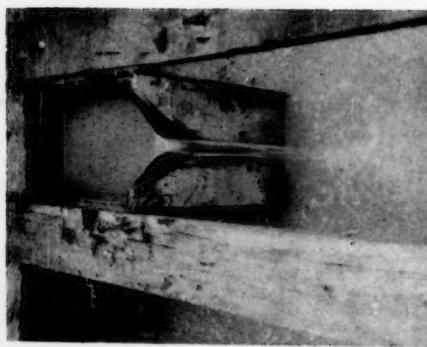
Plant B -- Raw sewage, gravity flow.

Figure 3. Flow measurement installations at plants A and B.

At the time sewage samples were being taken, a complete record of milk-products production in the processing plant was obtained. This included the pounds of milk received, pounds of butter churned, and the amount of skim and buttermilk dried. Surveys were made on June 30, July 1, and July 27, 1954, and on July 1, 2, and 8, 1955.

On July 2, 1955, the raw sample was the only one that could be taken since there was a pump failure early in the morning. On dismantling the pump, a three-inch rock was found lodged in the impeller. While the plant was being bypassed, the holding tank was drained and cleaned. The entire process of repairing the pump and cleaning the holding tank took approximately four hours.

During all surveys, the flow to and from the trickling filter remained practically constant as long as one or both pumps were operating. When both pumps were operating the filter received approximately 220,000 gallons of waste per day. When only one pump was operating, the filter received approximately 110,000 gallons of waste per day.

The raw flow varied considerably from hour to hour due to the type of operation occurring at the processing plant. Hydrographs of the hourly raw flow in 1954 and in 1955 are shown in Figures 4 and 5, respectively. The high peak flows in the morning are due to the operation of the can washer and to the butter washing activities. The increase in the flow about 10 P.M. is due to the clean up of equipment connected with the drying of the skim milk and buttermilk.

The temperature of the raw waste varied from a low of 62° F. to a high of 118° F. during the six surveys. The lower temperatures are due to the release of cold water used to cool cream and milk. The higher temperatures are due to the discharge of hot water from the can washer and other washing processes. Curves showing the temperatures of waste samples during the 1954 and 1955 surveys are also shown in Figures 4 and 5.

The pH of the raw wastes during 1954 and 1955 are shown in Figures 4 and 5. The pH of the raw waste varied from a low of 6.3 to a high of 9.2. The low pH was caused by the acid solution used in the can washer, and the high pH was caused by the washing compounds used in the general cleaning-up operations. The pH of the filter effluent and final effluent remained practically constant at 7.1 throughout all six surveys.

Test Results

Waste Characteristics

The laboratory determinations made on the waste samples included B.O.D., total solids, suspended solids, and total nitrogen. Due to a shortage of funds and laboratory personnel, total nitrogens, total solids, and suspended solids were run only during the 1954 surveys. All of the determinations were made in accordance with the ninth edition of Standard Methods for the Examination of Water, Sewage, and Industrial Wastes.[1]

A complete summary of the field data and chemical analysis of the wastes from plant A is shown in Table 1. The raw B.O.D., total solids, and suspended solids are shown as determined from actual sampling and also as back calculated from the analysis of the filter influent and filter effluent samples and the filter recirculation ratio. The raw flow from a milk processing plant varies from minute to minute. Since raw samples were taken only every half hour, the probability of missing a period of high B.O.D. in the raw sewage in
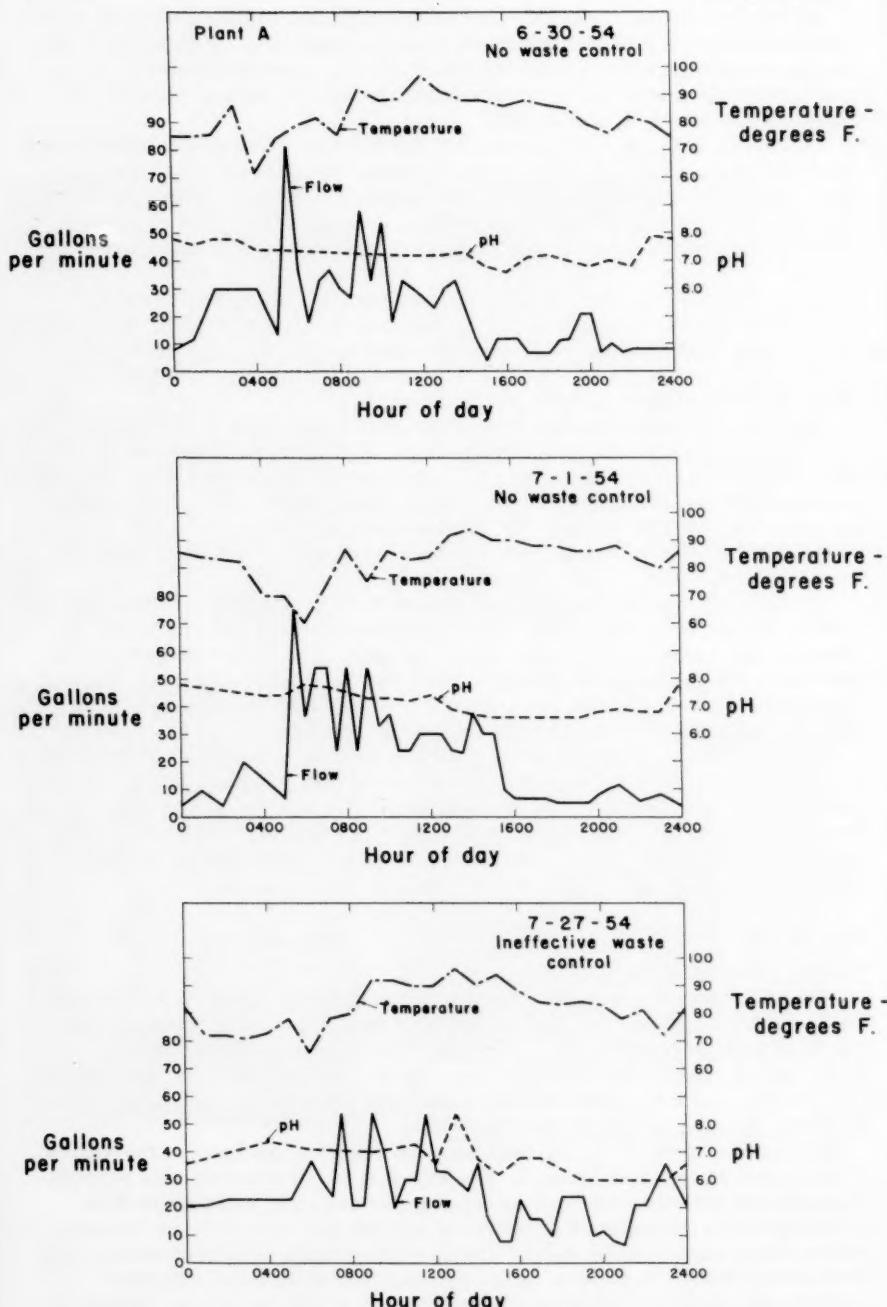
Figure 4.   Variations in flow, temperature, and pH at plant A in 1954 surveys.
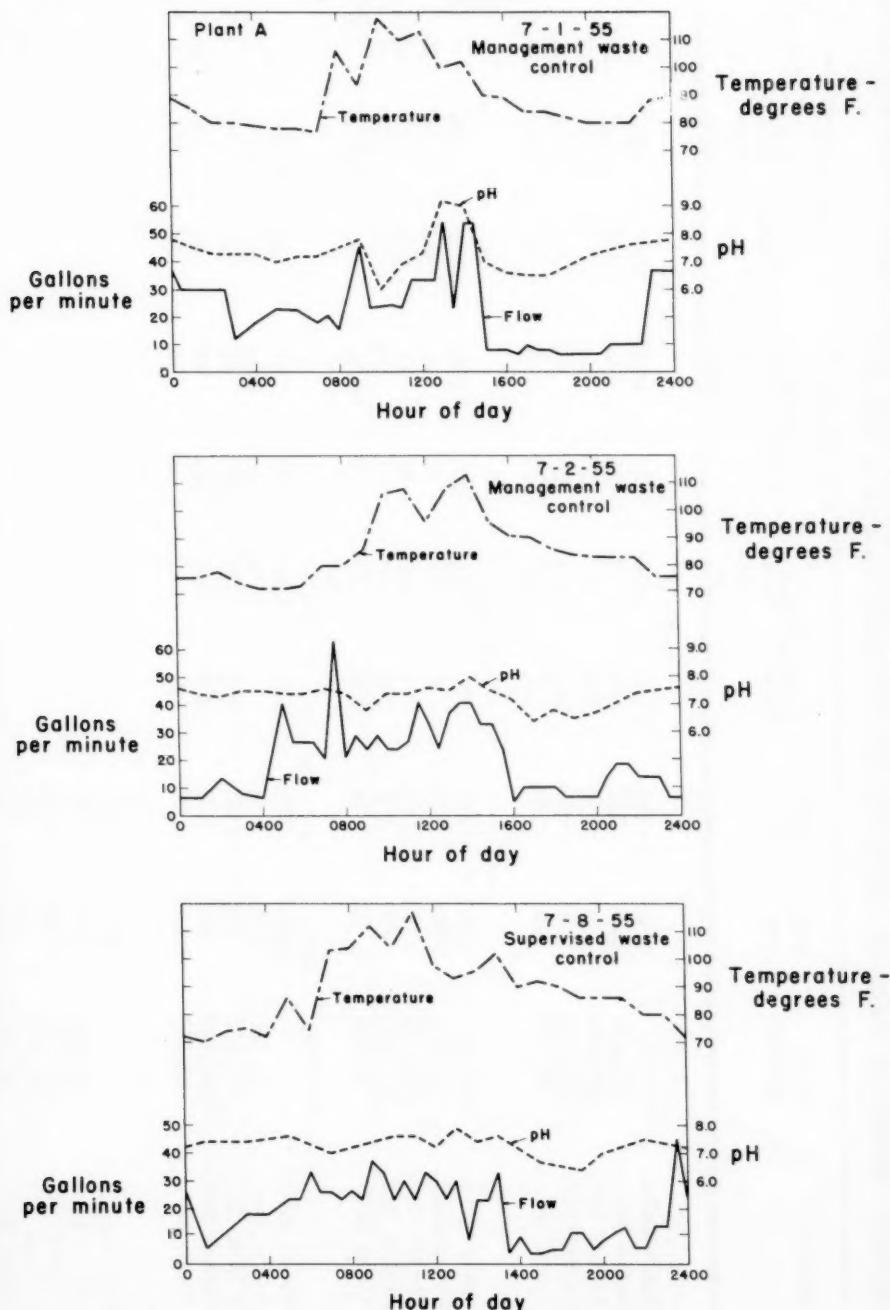
Figure 5.   Variations in flow, temperature, and pH at plant A in 1955 surveys.

Table 1. Summary of field and laboratory data for plant A surveys, 1954-1955

Source	Flow, gallons	BOD, ppm	BOD, lbs.	Total Solids Fixed	Total Solids Vola-tile ppm	Suspended solids Fixed	Suspended solids Vola-tile ppm	Dissolved solids Fixed	Dissolved solids Vola-tile ppm	Total N ppm
6-30-54										
Raw - Calc.		3560	790	1720	3250	660	2050	1060	1200	
Raw - Anal.	26,450	3270	725	484	2168	16	440	468	1728	25
Filter Inf.	231,580	780	1550	906	797	123	542	783	255	17
Filter Eff.	231,580	420	810	803	481	53	347	750	134	10
Final Eff.	26,450	110	24	737	211	10	51	727	160	3.8
7-1-54										
Raw - Calc.		3030	617	700	1740	200	1360	500	380	
Raw - Anal.	24,374	2900	589	336	1676	18	462	318	1214	18
Filter Inf.	231,580	570	1066	761	586	67	434	694	152	13
Filter Eff.	231,580	270	505	770	447	51	322	719	125	11
Final Eff.	24,374	67	14	703	163	2	30	701	133	1.9
7-27-54										
Raw - Calc.		2150	512	560	1190	220	500	340	690	
Raw - Anal.	28,587	2750	654		2978	138	1044	340	1934	34.6
Filter Inf.	231,580	750	1350	774	1228	206	854	768	374	17
Filter Eff.	231,580	540	975	806	1232	204	908	602	324	18.5
Final Eff.	28,587	110	26	690	452	38	126	652	326	4.8
7-1-55										
Raw - Calc.		3570	911							—
Raw - Anal.	30,747	1970	504							—
Filter Inf.	107,505	1320	1181							—
Filter Eff.	107,505	420	376							—
Final Eff.	30,747	130	34							—

Table 1. (Continued)

Source	Flow, gallons	BOD, ppm	BOD, lbs.	Total Solids		Suspended solids		Dissolved solids		Total N ppm
				Fixed	Volatile ppm	Fixed	Volatile ppm	Fixed	Volatile ppm	
Raw (flow only)	29,321				7-2-55					—
					7-8-55					
Raw – Calc.	26,958	2070	464							—
Raw – Anal.		1350	302							—
Filter Inf.	110,720	620	568							—
Filter Eff.	110,720	150	137							—
Final Eff.	26,958	50	9							—

sampling is high. The filter influent, filter effluent, and final effluent samples, however, are more representative of the actual waste. For example, the filter influent sample consisted of raw and recirculated sewage which was well mixed in the holding tank. The calculated B.O.D. of the raw sewage is, therefore, probably more nearly representative of the B.O.D. of the raw waste than the B.O.D. of the raw waste grab samples. The calculated B.O.D. of the raw sewage was used in all of the determinations involving the raw flow.

The raw flow at plant A varied from a high of 30,747 gallons per day on July 1, 1955, to a low of 24,374 gallons per day on July 1, 1954. The B.O.D. varied from a high of 3,570 ppm on July 1, 1955, to a low of 2,070 ppm on July 8, 1955. The B.O.D. of the final effluent varied from a high of 130 ppm on July 1, 1955, to a low of 40 ppm on July 8, 1955.

It is interesting to note that the volatile suspended solids decrease from the raw waste to the final effluent. Although there does not seem to be any uniform trend connected to this decrease, it is evident in each survey. The solids results for these surveys do not indicate much correlation between B.O.D. removal and volatile suspended solids removal. This same conclusion was reached by J. H. Sorrells and P. J. A. Zeller[2] in their work on trickling filter performance.

It is difficult to compare the operating results from one milk processing plant with the operating results from another when the waste production is expressed in terms of gallons per day and parts per million of B.O.D. For this reason, the waste volumes and strengths have been expressed in terms of units of the milk received. Table 2 shows the volumes and strengths of waste per 1,000 pounds of milk received at plant A during each of the six surveys. The volume of waste varied from a high of 144 gallons per 1,000 pounds of milk received at plant A during each of the six surveys. The volume of waste varied from a high of 144 gallons per 1,000 pounds of milk received on July 27, 1954 to a low of 106 gallons on July 8, 1955. The B.O.D. varied from a high of 3.78 pounds per 1,000 pounds of milk received on June 30, 1954, to a low of 1.83 pounds on July 8, 1955.

The average results from these surveys may be summarized as follows:

Table 2. Waste volumes and strengths observed at plant A

Date	Milk intake, lbs.	Flow gallons	B.O.D., lbs.	Flow per 1,000 lbs. milk intake	B.O.D., lbs. per 1,00 lbs. milk intake
6-30-54	209,424	26,450	790	126	3.78
7-1-54	205,602	24,374	617	119	3.01
7-27-54	198,370	28,578	512	144	2.58
7-1-55	270,676	30,747	911	114	3.37
7-2-55	273,770	29,321	----	107	----
7-8-55	254,436	26,958	464	106	1.83

Type of waste control	Ave. Flow, gal. per 1,000 lbs. milk intake	Ave. B.O.D., lbs. per 1,000 lbs. milk intake
1954 Results		
No waste control (6-30-54 and 7-1-54)	122	3.39
Management waste control (7-27-54)	144	2.58
1955 Results		
Management waste control (7-1-55 and 7-2-55)	110	3.37
Supervised waste control (7-8-55)	106	1.83

During the first two surveys at plant A, an average of 122 gallons of waste containing 3.39 pounds of B.O.D. were produced per 1,000 gallons of milk received. When waste saving techniques were pointed out to the plant management and instituted at the plant, the waste strength decreased to 2.58 pounds of B.O.D. per 1,000 pounds of milk. This represents nearly a 24 per cent decrease in waste strength. The volume of waste increased about 18 per cent during this period.

Between the surveys of 1954 and 1955, no attempt was made to continue to impress the plant management with the importance of waste prevention. As a result, in the initial survey in 1955, the waste strength climbed to 3.37 pounds of B.O.D. per 1,000 pounds of milk, a strength equivalent to that measured in the initial surveys in 1954. To determine the effect of rigidly supervised waste control, the control of waste production was assumed for one day by the survey personnel. On this day, the strength of the waste fell to 1.83 pounds of B.O.D. per 1,000 pounds of milk, a reduction of 46 per cent.

These results indicated that in plant A the use of waste prevention measures could reasonably be expected to reduce waste strengths by 25 to 50 per cent. To continue to obtain these reductions, however, a constant campaign for waste prevention would have to be waged in the plant.

Plant Loadings and Efficiencies

Treatment plant A operated in a satisfactory manner during all surveys and no nuisance conditions were apparent around the plant. Except for a few short periods of the day, the effluent had a crystal clear appearance. Occasionally, some sludge would rise to the surface in the final clarifier and pass over the outlet weir. This condition could be corrected by using a better means for sludge removal and by using an outlet baffle in the final clarifier.

The analytical and flow data in Table 1 were used to calculate hydraulic and organic unit loadings for the existing plant A treatment units. These unit loadings are tabulated in Table 3. The plant efficiency in B.O.D. removal during each survey is tabulated in Table 4.

The raw applied loadings to the trickling filters were all between 1,080 and 2,120 pounds of B.O.D. per acre-foot of filter per day. The total applied load, which varied due to the variation in recirculation, varied from 1,320 to 3,490 pounds of B.O.D. per acre-foot of filter per day. In all surveys, the

Table 3. Unit loadings observed at plant A

		Survey date					
		6-30-54	7-1-54	7-27-54	7-1-55	7-2-55	7-8-55
Holding tank	Raw flow detention, hrs.	8.05	8.74	7.45	6.95	7.28	7.90
	Total flow detention,* hrs.	0.92	0.95	0.98	1.98	—	1.93
Trickling filter	Raw applied						
	lbs. BOD/Ac.-ft./day	1830	1430	1190	2120	—	1080
	Total applied						
	lbs. BOD/Ac.-ft./day	3490	2475	3130	2740	—	1320
	Hydraulic loading, M.G.A.B.	4.57	4.43	4.26	2.12	—	2.18
	Recirculation ratio	7.75	8.25	6.61	2.5	—	3.11
Final clarifier	Overflow rate, ga./sq.ft./day	236	214	254	274	—	240
	Detention, hrs.	4.5	4.9	4.2	3.9	—	4.4
Digester, cu.ft./capita**		0.47	0.58	0.52	0.675	1.05	1.13

* Raw flow plus recirculated flow
** Based on B.O.D. population equivalent

B.O.D. removal was greater than 96.2 per cent. The recirculation ratio, the ratio of the recirculated flow to the raw flow, was such that the hydraulic loadings on the filter varied between 2.12 and 4.57 million gallons of waste per acre-foot of filter per day.

The percentage B.O.D. removal decreased as the raw loadings increased as follows:

Table 4. Efficiencies of B.O.D. removal observed at plant A, in per cent

Unit	6-30-54	7-1-54	7-27-54	7-1-55	7-9-55
Trickling filter (Raw plus re-circulation)	47.6	52.6	27.8	68	73
Final clarifier	74	77	80	68	75
Overall plant	97.0	97.6	97.0	96.2	98.2

Raw applied B.O.D., lbs. per acre-ft. per day	Per cent B.O.D. removal
1,080	98.2
1,190	97.0
1,430	97.6
1,830	97.0
2,120	96.2

The data for the 1,190 pound filter loading does not follow the general trend of removal. On the day that this survey was made, the filter was un-loading. As a result, the total applied load to the filter was disproportionate-ly high and the B.O.D. removal was reduced over what would normally have been expected.

The percentage removal of B.O.D. also decreased as the total applied loadings increased as follows:

Total applied B.O.D. lbs. per acre-ft. per day	Per cent B.O.D. removal
1,320	98.2
2,475	97.6
2,740	96.2
3,130	97.0
3,490	97.0

The loading of 3,130 represents data from the survey on the day that the filter was observed to unload. When the B.O.D. removal on this day was based on total applied load, as above, the results follow the trend established by the other surveys. The data for the 2,740 pound loading does not, however, follow the trend of the other data. On this day, the hydraulic loading to the fil-ter was only 2.12 million gallons per acre per day, a loading which is con-siderably below the recommended minimum for high rate filters.

On the basis of these data, plant A would be expected to provide greater than 97 per cent B.O.D. removal under the following conditions.

Raw B.O.D., lbs. per acre-foot per day   1,500 or under
Total applied B.O.D., lbs. per acre-foot per day   3,000 or under
Hydraulic loading, M.G.A.D.   5.0

The capacity of the holding tank, 8,800 gallons, was about equal to one-third of the total raw flow. In 1954, the average detention in the holding tank based on raw sewage only was 8.08 hours. In 1955, the average detention in the holding tank based on raw sewage only was 7.37 hours. In 1954, both raw sewage pumps were used to recirculate the contents of the holding tank to the filter and back to the holding tank. The detention time in the holding tank based on the raw flow plus the recirculation averaged 0.95 hours. In 1955, only one pump was operated in order to conserve power and to provide filter operating results using another hydraulic loading. The average detention in the holding tank of the raw plus recirculation was 1.95 hours. In view of the satisfactory plant operation under these conditions, it may be concluded that the holding tank should have a capacity equal to about one-third of the total raw flow.

The detention time and surface settling rate in the final clarifier in plant A appear to be more than adequate. The surface settling rate averaged about 250 gallons per square foot per day, while the loading generally recommended is about 800 gallons per square foot per day. The detention time in the clarifier averaged about 4 1/2 hours, though 1 1/2 hours is generally considered adequate.[3]

The digester capacity varied between 0.47 and 1.13 and averaged about 0.7 cubic feet per capita when based upon a B.O.D. population equivalent. The digestion capacity at plant A was too small since the sludge was only partially digested when it had to be removed at about monthly intervals.

Plant B Studies

Milk Handling Procedures

Plant B receives about 100,000 pounds of whole milk in cans directly from the producers daily. About 65 per cent of the milk is collected by route trucks while the remainder is brought in by the individual farmer. The milk from each producer is dumped into a weighing vat, the weight is recorded, and the vat contents are discharged into a storage tank. The milk is then pasteurized, and about 30,000 pounds per day is separated. The cream obtained from the suspended milk is cooled and stored until the next day when it is churned into butter. The skim milk, buttermilk, and the remainder of the whole milk is cooled and stored in large tanks from which it is transferred into insulated trucks and taken to another plant for further processing. About 10 per cent of the butter is cut and wrapped in one pound packages for local sale. The remainder of the butter is shipped to Chicago.

During the summer months milk begins to arrive at the plant at about 8 A.M., and the last can is generally emptied by 2 P.M. This schedule varies somewhat from month to month and may be extended during periods of bad weather and poor road conditions.

The liquid wastes coming to the treatment plant originate from the following sources:

1. Can dumping and draining.
2. Can washer.

3. Separator and pasteurizer drippings.
4. Cooler cabinet drippings.
5. Churning and butter washing.
6. Storage vats.
7. Miscellaneous leakage around pump packings, valves, and unions.
8. Clean up.
9. Three rest rooms.

Waste Treatment Plant

The waste treatment plant used to treat the plant B wastes consists of the following:

1. Holding tank - 7,575-gallon capacity.
2. Three centrifugal sewage pumps: two with 50 gallons per minute capacity, one with 32 gallons per minute capacity.
3. Primary filter with a rock volume of 0.02225 acre-feet.
4. Intermediate clarifier with a capacity of 4,260 gallons.
5. Secondary filter with a rock volume of 0.02225 acre-feet.
6. Final clarifier with a capacity of 2,025 gallons.
7. Diversion weir to recirculate final clarifier effluent to the holding tank.

A plan of this plant is shown in Figure 6, and some general views are shown in Figures 7 and 8. Approximately two-thirds of the raw sewage enters the holding tank from a pump. A 50-gpm. float-controlled, sewage pump is used for this purpose. A 32-gpm pump discharges the raw and recirculated sewage from the holding tank to the primary filter. From this filter the sewage flows by gravity into the intermediate clarifier where a 50-gpm pump discharges the settled sewage to the secondary filter. The sewage then flows from this filter into a diversion box that diverts part of the flow to the intermediate clarifier and the remainder to the final clarifier. Part of the final effluent is recirculated to the holding tank and the remainder is discharged to the receiving stream. The recirculation system operates 24 hours a day.

Raw sewage starts to flow into the treatment plant at about 7 A.M. when butter making begins. The flow remains fairly constant until the cleanup of the various departments begins about noon. The flow increases rapidly at this time and remains high until the cleanup is over around 3 P.M. when the flow drops off sharply. Between 4 P.M. and 4:30 P.M. the raw flow stops completely. From then until 7 A.M. the next day the waste treatment plant continues to recirculate the sewage within the plant. During this period of operation, a portion of the final effluent is discharged and the remainder is recirculated. By 7 A.M. the liquid level in the holding tank is at a minimum and the treatment plant is ready to receive the next day's flow.

Test Procedure

Sewage samples were collected every 30 minutes at five points throughout the treatment plant. The sources of these samples were: raw gravity flow, raw pumped flow, primary filter influent, secondary influent, and final effleunt. The volume of sewage added to each sample was proportional to the quantity of flow. The samples for the raw flow were proportioned by measuring the raw gravity and raw pumped flow. The two raw samples were combined to provide a single raw sewage sample. The final effluent samples were proportioned according to the plant discharge and both filter influent samples were proportioned according to pump discharge.
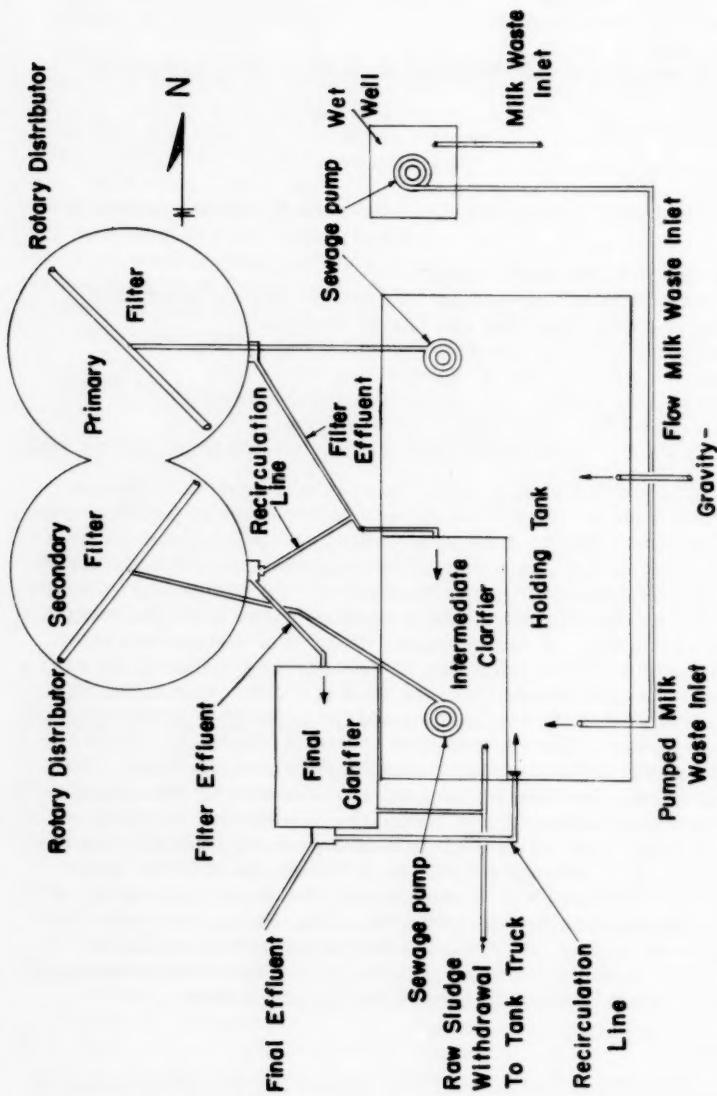
Figure 6. Schematic plan view of existing plant B.
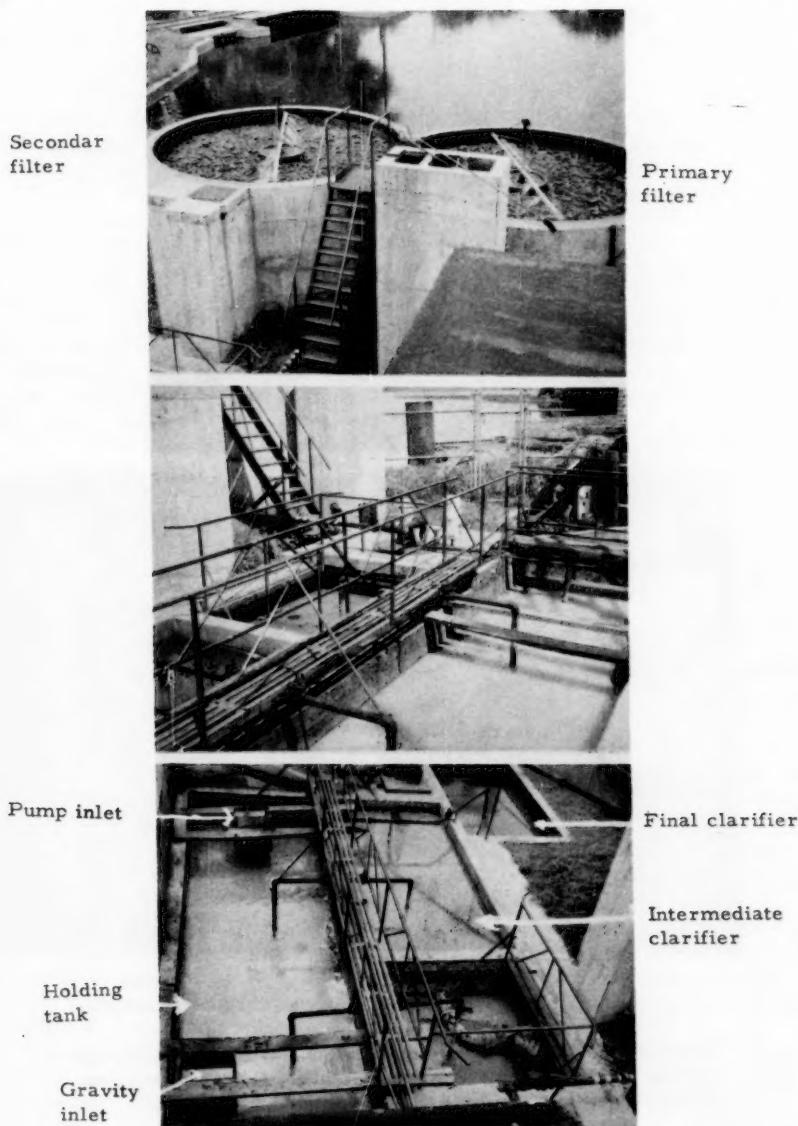
Figure 7. General views of plant B showing at top, trick-
ling filters; center, the holding tank; and at the bottom,
clarifiers.

Primary filter

Secondary filter
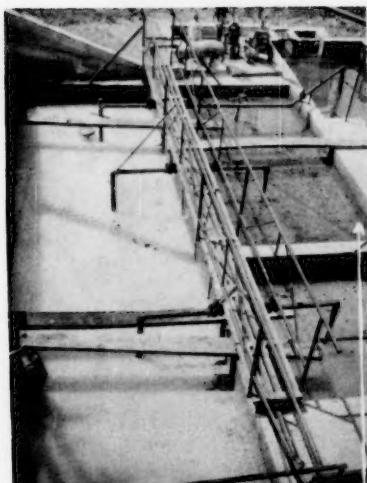
Holding tank
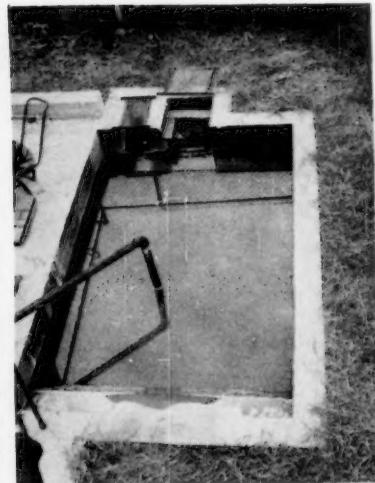
Intermediate clarifier

Final clarifier

Figure 8. Close-up views of plant B showing at top, sewage leaving rotary distributors and at center, the sewage in the holding tank, intermediate clarifier and final clarifier.

To measure the raw flow, two V-notch weirs were constructed and placed on the gravity-flow inlet and pumped-flow inlet pipes. The weirs may be seen in Figure 3. The calibrations of the pumps discharging to the filters were accomplished by measuring the drawdown in the holding tank or the intermediate clarifier when no flow was entering these tanks. One pump discharged to the primary clarifier at a rate of 32 gallons per minute; the other pump discharged to the final filter at a rate of 50 gpm.

The flow, temperature, pH, dissolved oxygen, and physical characteristics of the samples were recorded in the field. The B.O.D., nitrogen, and solids were determined in the sanitary engineering laboratory at the Iowa State College. The samples were iced at all times during the period of collection and transportation to the laboratory. While the sewage samples were being taken, a complete record of the production in the creamery was obtained. This included the pounds of milk received, pounds of butter churned, and the amounts of whole, skim, and buttermilk shipped. Complete sanitary surveys of the waste treatment plant operation were made on July 15, 16, August 12, 13, 1954, and August 19, 20, 26, 27, 1955.

Since each filter pump discharged at a constant rate, each filter received a constant volume of water during the eight surveys. The primary filter was dosed with 46,500 gallons of waste per day and the secondary filter was dosed with 72,000 gallons per day.

The raw flow varied considerably at this plant as shown in Figures 9 and 10. It was zero from about 4 P.M. to 7 A.M. and then raised to a maximum at about 1:30 P.M. The maximum flow occurred during the cleanup period. The milk receiving room, separating, storage, and pasteurization room, and the butter room are all cleaned up at about the same time, thereby creating a high peak hourly flow. The instantaneous hourly flows for 1954 and 1955 are shown in Figures 9 and 10 respectively. Average hourly flows in 1954 and 1955 are shown in Figure 11. The flows in 1955 were considerably less than the flows in 1954. This was due mainly to the fact that the cream cooling water was separated from the sanitary sewer system in October, 1954. This uncontaminated cooling water was discharged directly to the receiving stream in 1955.

The temperature of the raw flow varied from lows of 60° F. in 1954 and 66° F. in 1955 to a high of 98° F. in both years. The lower temperatures recorded in 1954 were due to the cream cooling water which was discharged from the cream cooler at about 45° F. The high temperatures were due to the release of the wash water used in the can washer and the warm water used in the general washing of piping, pumps, storage tanks, and utensils. The hourly raw waste temperatures during the 1954 and 1955 surveys are shown in Figures 9 and 10.

The pH of the raw waste varied from a low of 6.2 to a high of 8.4. As at plant A, the low pH was due to the use of an acid solution in the can washer and the high pH was caused by the use of washing compounds in the general cleaning-up operation. The hourly variations in the raw pH during 1954 and 1955 are shown also in Figures 9 and 10. The pH of the primary filter effluent, secondary filter effluent, and plant effluent remained practically constant at 7.2 throughout all eight surveys.
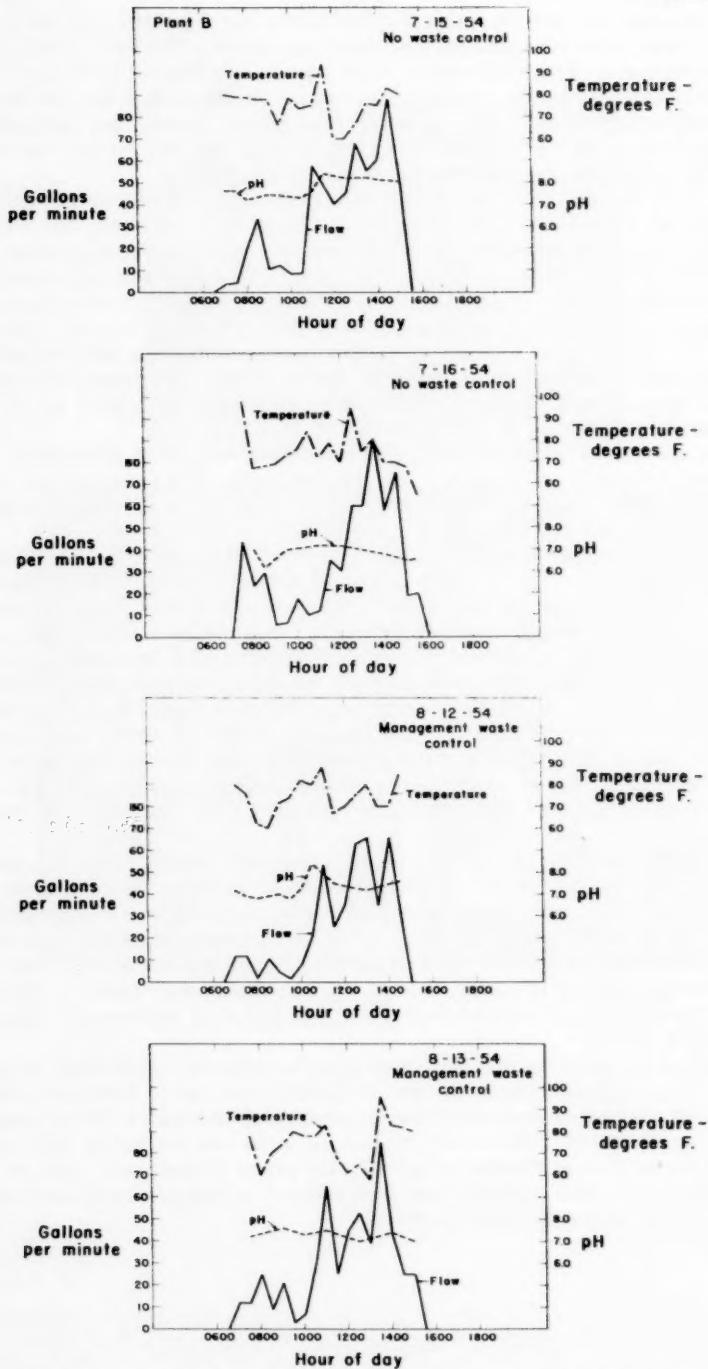
Figure 9. Variations in flow, temperature, and pH at plant B in 1954 surveys.
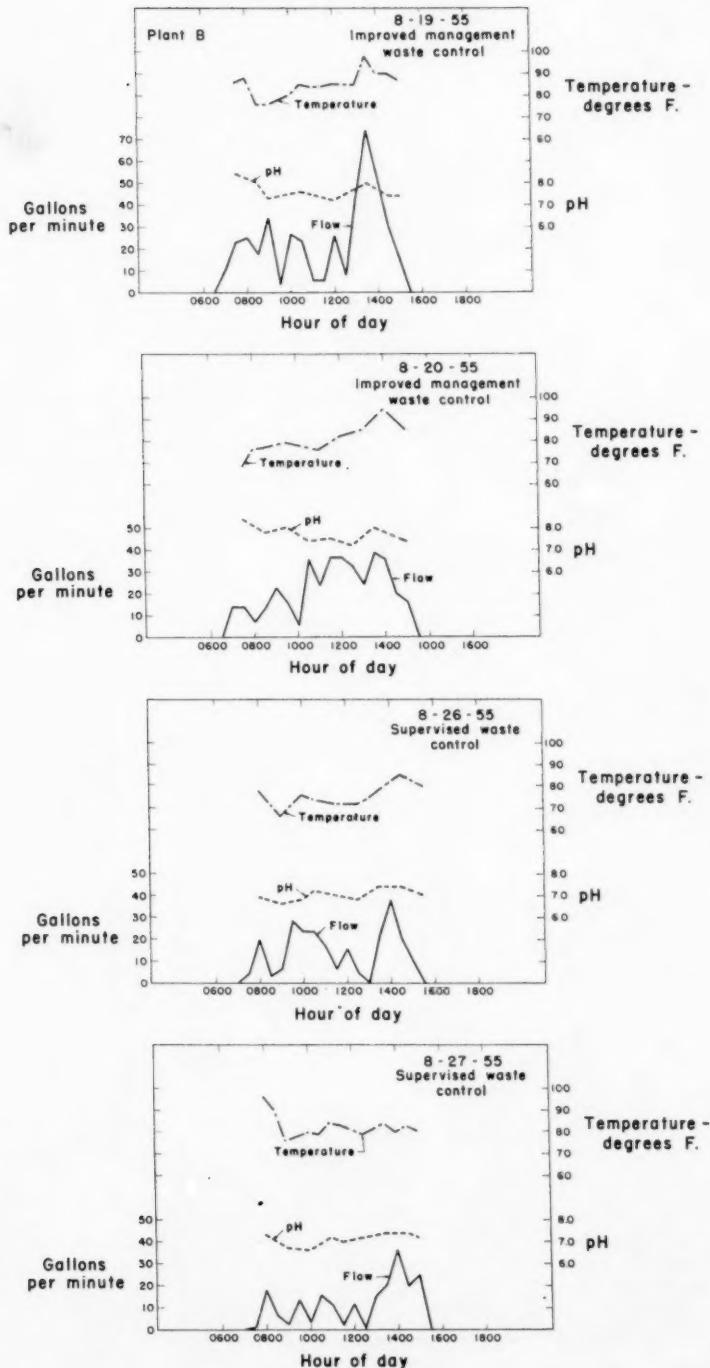
Figure 10.   Variations in flow, temperature, and pH at plant B in 1955 surveys.
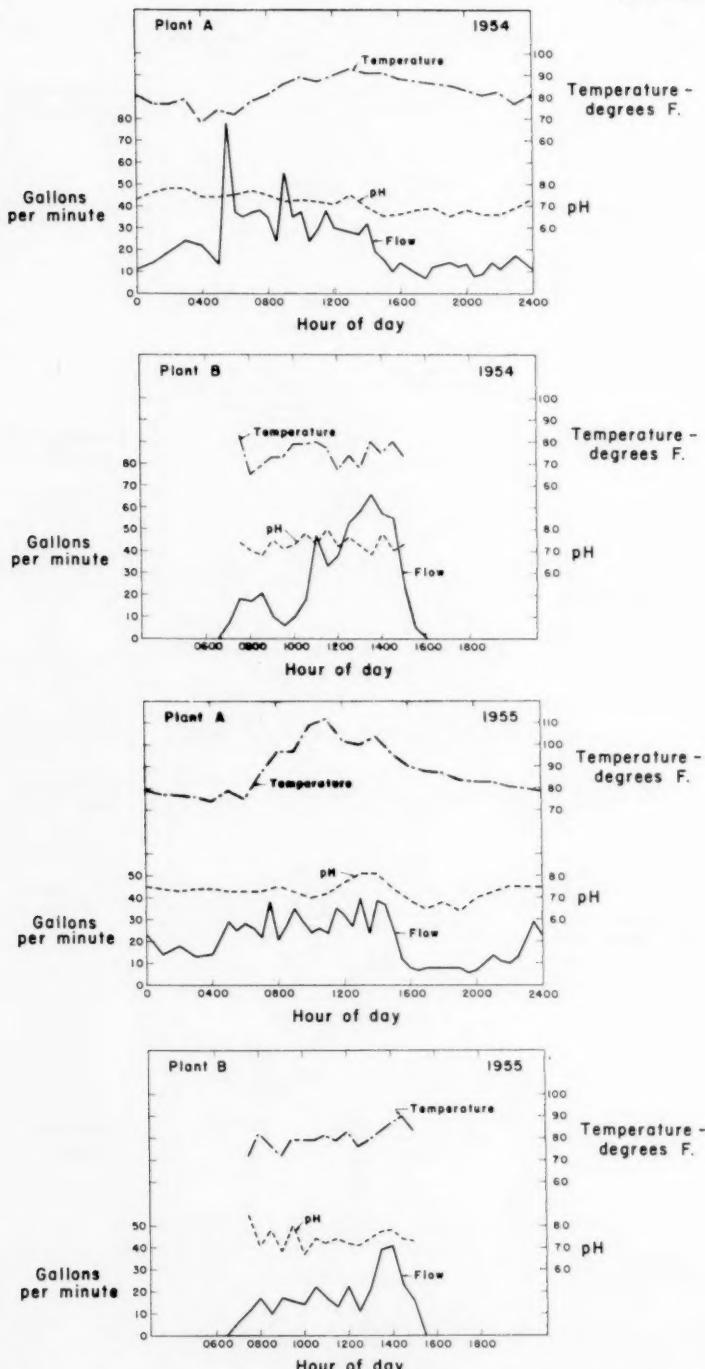
Figure 11. Comparison of average variations in flow, temperatures, and pH at plants A and B in 1954 and 1955.

Test Results

Waste Characteristics

All laboratory determinations were made in accordance with the ninth edition of Standard Methods for the Examination of Water, Sewage, and Industrial Wastes.[1] In 1954, the laboratory determinations made on the waste included B.O.D., total nitrogen, total solids, and suspended solids. Due to a shortage of funds and laboratory personnel, only the B.O.D. was run during the 1955 survey.

A complete summary of the field data and laboratory analysis of the wastes from plant B is shown in Table 5. The B.O.D., total solids, and suspended solids in the raw sewage are shown as determined from actual sampling and also as calculated from knowing the analysis of the filter influent and final effluent samples and the recirculation ratio. The calculated values for the raw waste were used in the remainder of the determinations involving the raw flow.

At plant B, the B.O.D. of the raw waste varied from a high of 195 pounds on August 12, 1954, to a low of 73 pounds on August 26, 1955. This wide range is due to the extensive plant cleanup that was initiated on August 26, 1955. This waste cleanup will be discussed later in this section. All leaky unions and valves were repaired and the drippings were caught to prevent them from entering the floor drains. The butter was churned without washing, thereby eliminating the butter wash water from the waste treatment plant.

The B.O.D. of the final effluent varied from a high of 140 ppm on July 15, 1954, to a low of 30 ppm on August 26, 1955. The high B.O.D. recorded for the final effluent on July 15, 1954, and August 12, 1954, is due in part to the reversal of flow from the holding tank to the final effluent. The flow normally is from the final clarifier effluent to the holding tank; however, when the water elevation gets too high in the holding tank the flow is reversed. A flap valve had been placed on this line but it malfunctioned for a short time and stuck in the open position on the above dates.

Table 6 shows the volumes and strengths of the wastes observed at plant B in relation to the quantity of milk received. In comparing the quantity of the waste to the amount of milk received, it is noted that the flow varied from a maximum of 201 gallons to a minimum of 80 gallons per 1,000 pounds of milk received. The B.O.D. varied from a maximum of 2.10 pounds to a minimum of 0.81 pounds per 1,000 gallons of milk received.

The average waste volumes and strengths determined in the eight surveys may be summarized as follows:

Type of waste control	Ave. flow, gal. per 1,000 lbs. milk intake	Ave. B.O.D., lbs. per 1,000 lbs. milk intake
1954 results		
No waste control (7-15-54 and 7-16-54)	166	1.53
Ineffective management waste control (8-12-54 and 8-13-54)	158	1.82
1955 results		
Management waste control (8-19-55 and 8-20-55)	122	1.73
Supervised waste control (8-26-55 and 8-28-55)	81	0.95

Table 5. Summary of field and laboratory data for plant B surveys, 1954-1955

Source (see legend)*	Flow, gallons	BOD, ppm	BOD, ppm	Total solids		Suspended solids		Dissolved solids		Total N ppm
				Fixed	Vola-tile ppm	Fixed	Vola-tile ppm	Fixed	Vola-tile	
				7-15-54						
1	17,963	930	142	321	296	17	200	300	93	
2		1190	182	712	572	174	306	538	266	48
3	46,500	445	172	402	200	26	122	376	78	44
4	72,000	240	144	388	165	34	84	354	81	34
5	18,355	140	14	410	129	30	66	380	63	29
				7-16-54						
1	14,819	1580	189	660	380	25	250	635	130	
2		1320	158	1875	461	82	218	1793	243	38
3	46,500	560	236	933	218	26	128	907	90	32
4	72,000	220	132	952	200	38	118	914	82	31
5	14,350	80	10	1006	139	26	70	980	69	28
				8-12-54						
1	13,495	1640	195	420	1290	54	470	370	820	
2		1640	185	338	1035	40	422	298	613	45
3	46,500	560	217	380	491	26	174	354	317	21
4	72,000	215	129	347	261	18	82	329	279	13
5	14,250	120	14	378	200	16	66	362	134	9

* Legend:
1 - Raw sewage, calculated
2 - Raw sewage, analysis
3 - Primary filter, influent
4 - Secondary filter, influent
5 - Final effluent

Table 5. (Continued)

Source (see legend)*	Flow, gallons	BOD, ppm	BOD, lbs.	Total solids Fixed ppm	Total solids Volatile ppm	Suspended solids Fixed ppm	Suspended solids Volatile ppm	Dissolved solids Fixed ppm	Dissolved solids Volatile ppm	Total N ppm
						8-13-54				
1	15,850	1130	146	470	530	70	240	400	290	39
2	46,500	980	127	262	572	26	208	236	364	14
3	72,000	440	171	387	318	32	108	357	210	8
4	15,536	130	78	360	210	16	72	343	142	8
5		85	11	340	210	12	40	332	173	4
						8-19-55				
1	12,020	1750	175			—				—
2	46,500	1750	175			—				—
3	72,000	520	200			—				—
4	11,780	200	120			—				—
5		90	9			—				—
						8-20-55				
1	10,887	1680	151			—				—
2	46,500	1620	146			—				—
3	72,000	450	175			—				—
4	11,128	190	114			—				—
5		75	7			—				—
						8-26-55				
1	7,275	1180	73			—				—
2	46,500	1080	65			—				—
3		210	81			—				—

* Legend: 1 – Raw sewage, calculated   4 – Secondary filter influent
2 – Raw sewage, analysis   5 – Final effluent
3 – Primary filter influent

Table 5. (Continued)

Source (see legend)*	Flow, gallons	BOD, ppm	BOD, lbs.	Total solids Fixed ppm	Total solids Vola-tile ppm	Suspended solids Fixed ppm	Suspended solids Vola-tile ppm	Dissolved solids Fixed ppm	Dissolved solids Vola-tile ppm	Total N ppm
					8-26-55 (continued)					
4	72,000	85	51							—
5	7,452	30	2							—
					8-27-55					
1	7,079	1630	96							—
2		730	43							—
3	46,500	280	108							—
4	72,000	100	60							—
5	7,010	40	2							—

*   Legend: 1 - Raw sewage, calculated
            2 - Raw sewage, analysis
            3 - Primary filter influent
            4 - Secondary filter influent
            5 - Final effluent

Table 6. Waste, volumes and strengths observed at plant B

Date	Milk intake, lbs.	Flow, gallons	B.O.D., lbs.	Flow per 1,000 lbs. milk intake	B.O.D., pounds per 1,000 lbs. milk intake
7-15-54	106,122	21,355	142	201	1.34
7-16-54	109,195	14,350	189	131	1.73
8-12-54	92,761	14,250	195	154	2.10
8-13-54	94,510	15,536	146	162	1.54
8-19-55	95,275	11,780	175	124	1.84
8-20-55	92,821	11,128	151	120	1.63
8-26-55	90,256	7,452	73	83	0.81
8-27-55	88,591	7,010	96	80	1.08

During normal operations without special thought of waste control, plant B produced about 166 gallons of waste containing 1.53 pounds of B.O.D. per 1,000 pounds of milk intake. When waste saving techniques were pointed out to the management and theoretically instituted at the plant, the waste volume was reduced slightly and the waste strength was increased. In other words, the waste control was ineffective. A part of the increase in waste strength may be due to the reduction in milk intake from an average of about 107,600 pounds in the first two surveys to about 93,600 pounds in the second two surveys.

Before starting the 1955 surveys, the management was asked to divert the uncontaminated cream cooling water from the treatment plant. The management was again instructed in the proper use of waste savings techniques. During the first two surveys in 1955, management waste control was evidently ineffective, since an average of 122 gallons of waste containing 1.73 pounds of B.O.D. were still produced per 1,000 pounds of milk received. Most of the volume reduction may be attributed to the diversion of the cream cooling water directly to the receiving stream.

During the last two surveys in 1955, the waste prevention program was rigidly supervised by the survey personnel. During this period, the waste averaged 81 gallons containing 0.95 pounds of B.O.D. per 1,000 pounds of milk received. These data represent volume reductions of 50 per cent over the original waste volume observed in 1954 and a reduction of about 33 per cent over the waste volume observed after the cream cooling water was diverted from the treatment plant. The data indicate that the strength of the waste was reduced about 47 per cent from the average waste strength observed in 1954.

The results from plant B indicate that waste prevention measures may reasonably be expected to reduce waste strengths and waste volumes. To continue to obtain these reductions, however, a constant waste control campaign must be waged in the milk processing plant.

Plant Loadings and Efficiencies

From every standpoint, this plant operated satisfactorily during all surveys, and there was no evidence of pollutional conditions in the receiving stream. The receiving stream had an average flow of about 0.2 cubic feet per second during the eight surveys. The stream discharge rate was controlled with a discharge valve from an impounding reservoir.

The data shown in Table 5 for the eight surveys were used to calculate the unit loadings for the existing treatment units at plant B. The calculated unit loadings are tabulated in Table 7. The corresponding unit efficiencies based on B.O.D. removal are shown in Table 8.

The holding tank has a capacity of 7,575 gallons. The detention in the holding tank varied, therefore, as the raw flow varied. On July 15, 1954, the detention time for the raw waste was 10.1 hours, while on August 27, 1955, after waste prevention measures were initiated, the detention time was 25.7 hours. The actual detention of raw plus recirculated flow remained constant at 3.9 hours in all surveys. This was accomplished by increasing the recirculation ratio through the holding tank from 1.59 to 5.6 as the raw flow decreased.

The raw applied loadings to the primary trickling filter varied between 3,280 and 8,750 pounds of B.O.D. per acre-foot of filter per day. The total applied load, which varied due to the variations in recirculation, varied between 3,640 and 10,600 pounds of B.O.D. per acre-foot per day. In all but one

Table 7. Unit loadings observed at plant B

Unit		Survey date							
		7-15-54	7-16-54	8-12-54	8-13-54	8-19-55	8-20-55	8-26-55	8-27-55
Holding tank	Detention, hours Raw flow	10.1	12.3	13.5	11.5	15.1	16.7	25	25.7
	Total flow**	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
Primary trickling filter	Organic loading, lbs. BOD/Ac.-ft./day Raw applied	6380	8500	8750	6550	7860	6780	3280	4260
	Total applied	7700	10600	9750	7660	9020	7850	3640	4850
	Hydraulic loading, M.G.A.D.	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2
	Recirculation ratio**	1.59	2.13	2.44	1.93	2.67	3.28	5.4	5.6
Intermediate clarifier	Overflow ratio, gal./sq.ft./day	447	447	447	447	447	447	447	447
	Detention, hours	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Secondary trickling filter	Organic loading, lbs. BOD/Ac.-ft./day	6460	5940	5800	3500	5400	5120	2290	2700
	Hydraulic loading, M.G.A.D.	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.4
	Recirculation ratio**	3.0	3.19	4.34	3.54	4.98	5.63	8.9	9.15
Final clarifier	Overflow rate, gal./sq.ft./day	1200	1200	1200	1200	1200	1200	1200	1200
	Detention, hours	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68

*   Raw flow plus recirculated flow

** $\dfrac{\text{Recirculated flow}}{\text{Raw flow}}$

Table 8. Efficiencies of B.O.D. removal observed at plant B, in per cent

Unit		Date							
		7-15-54	7-16-54	8-12-54	8-15-54	8-19-55	8-20-55	8-26-55	8-27-55
Primary filter and intermediate clarifier	B.O.D. in raw flow	74	86	87	89	88	89	93	94
	Total applied B.O.D.	46	61	62	70	62	58	59	64
Secondary filter and final clarifier, based on total applied B.O.D.		42	64	44	35	55	60	65	60
Overall plant removal, based on B.O.D. in raw and final flows		85	95	93	92	95	96	97	97

survey, the overall plant B.O.D. removal was greater than 92 per cent as
follows:

Primary filter raw applied B.O.D., lbs./acre-foot/day	Overall plant B.O.D. removal, per cent
3,280	97
4,260	97
6,380	85
6,550	92
6,780	96
7,860	95
8,500	95
8,750	93

These data indicate that about 92 per cent or greater overall plant B.O.D.
removal may normally be expected in this plant for primary filter loadings
up to about 8,800 pounds per acre-feet per day. The actual B.O.D. removal
in the primary filter based on the total applied load was as follows:

Primary filter total applied B.O.D., lbs./acre-foot/day	Removal of B.O.D. in primary filter and intermediate clarifier, per cent
3,640	59
4,850	64
7,660	70
7,700	46
7,850	58
9,020	62
9,750	62
10,600	61

These data indicate that the B.O.D. removal for the primary filter will be
approximately 58 to 62 per cent for total B.O.D. loadings between 3,640 and
10,600 pounds of B.O.D. per acre-foot per day.

During all of the surveys, the hydraulic loading to the filter was constant
at 13.2 million gallons per acre per day. This hydraulic loading was suffi-
cient to prevent filter ponding in all surveys. To achieve this hydraulic load-
ing, the amount of final effluent recirculated to the holding tank increased
from 1.59 times the raw flow early in 1954 to 5.60 times the raw flow late in
1955.

The primary trickling filter had a maximum loading of raw applied B.O.D.
of 8,750 pounds per acre-foot per day on August 12, 1954. The minimum
loading was 3,290 pounds of B.O.D. per acre-foot per day on August 26, 1955.
The large reduction in filter loading was the result of rigid waste control
measures enforced by the survey personnel.

The intermediate clarifier had surface settling or overflow rates and de-
tention times that were more than adequate. The surface settling rates aver-
aged 447 gallons per square foot per day while the recommended limit is
1,000 gallons per square foot per day.[3] The detention period in the inter-
mediate clarifier was constant at a theoretical 2.2 hours. The recommended
minimum detention time for settling tanks is one and one-half hours.[3]

The secondary filter had a maximum loading of 6,460 pounds of B.O.D. per
acre-foot per day on July 15, 1954, and a minimum loading of 2,290 pounds on

August 26, 1955. The secondary filter loadings and efficiencies in B.O.D. removal may be summarized as follows:

Secondary filter total applied B.O.D., lbs./acre-foot/day	Removal of B.O.D. in secondary filter and final clarifier, per cent
2,290	65
2,700	60
3,500	35
5,120	60
5,400	55
5,800	44
5,940	64
6,460	42

The drop in B.O.D. applied to the secondary filter was the result of the waste control program within the milk processing plant. The hydraulic loading on the secondary filter was constant at 20.4 million gallons per acre per day. To maintain this hydraulic loading, the recirculation increased from 3.01 times the raw flow.

The surface settling rate in the final clarifier was 1,200 gallons per square foot per day, and the detention time was 0.68 hour. The recommended surface settling rate for a final clarifier is 800 gallons per square foot per day, and the recommended detention time is one and one-half hours.[3] Although it would appear, therefore, that the existing final clarifier was too small, no detrimental effect on the final effluent was observed.

There was no digester at plant B. Sludge was removed weekly from the hoppers in the intermediate and final clarifiers and was disposed of in a gravel pit. The gravel pit was dry and no odor or other nuisance was created by disposing of the sludge in this manner.

CONCLUSIONS

The following conclusions are based on the results obtained during this study.

1. With unit loadings and recirculation ratios comparable with those measured in this study, Tables 3 and 7, a single-stage, high-rate trickling filter plant may be expected to remove from 96 to 98 per cent of the raw B.O.D., and a two-stage high-rate trickling filter plant may be expected to remove from 92 to 97 per cent of the raw B.O.D. These removals were satisfactory for the two plants investigated; however, they cannot be deemed as satisfactory for all milk plant installations.

2. Supervised waste saving measures used in the processing plant were effective in reducing the B.O.D. discharged to the waste treatment plants by approximately 45 per cent. The reduction in water usage at plant A was 19.5 per cent, and the reduction at plant B was 50 per cent. These reductions in waste demonstrate the value of good housekeeping in the processing plant. By practicing good waste saving measures, a milk processing plant can reduce the strength and volume of wastes discharged, which will in turn reduce the cost of waste treatment.

REFERENCES

1. American Public Health Association, American Waterworks Association and Federation of Sewage and Industrial Wastes Association. Standard Methods for the Examination of Water, Sewage and Industrial Wastes. 10th Ed. N. Y., American Public Health Association, Inc. 1955.

2. Sorrels, J. H. and Zeller, P. J. A. Effect of Recirculation on Trickling Filter Performance. Sewage and Industrial Wastes. 27:415-430. 1955.

3. Iowa State Department of Health, Division of Public Health Engineering. Policies Governing Preparation and Submission of Plans and Specifications for Sewer Systems and Sewage Treatment Plants. Des Moines, Iowa. 1952.

Journal of the
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

SEWAGE TREATMENT BY RAW SEWAGE STABILIZATION PONDS

W. W. Towne,* M. ASCE, and ,W. H. Davis **
(Proc. Paper 1337)

SUMMARY

Treatment of sewage in stabilization ponds has received considerable attention since World War II. The U. S. Public Health Service conducted co-operative field studies with North and South Dakota in 1955 and 1956 at ponds serving five communities in those two States. One of the primary purposes of this study was to develop additional information on the design, operation, and applicability of such facilities for treating raw sewage. A limited evaluation of existing operating data on "oxidation" ponds was also carried out in cooperation with the Texas State Department of Health during the summers of 1955 and 1956. This paper summarizes data from these studies and discusses some of the factors affecting the process of purification and criteria requiring consideration in the design of stabilization ponds.

INTRODUCTION

A waste stabilization pond is a structure specifically designed to treat liquid organic wastes by biological, chemical, and physical processes commonly referred to as natural self-purification. Design of the structure should include facilities for the maximum utilization of the processes of purification commensurate with economy of construction and operation. In other words, the designing engineer, with a knowledge of the purification phenomena involved, designs a facility that will permit these processes to proceed efficiently in a controlled environment.

The need for water reclamation in some of the arid sections of the country, as well as a general need for a more economical method of sewage treatment,

has given increased impetus to the use of such facilities in recent years. This method has proved especially advantageous for small communities where per capita cost of conventional treatment is high and revenue raising powers are low.

In the more arid sections of the country, waste stabilization ponds have generally been used as secondary or tertiary treatment units, with one of the primary objectives being to salvage water for subsequent use, usually irrigation. Following World War II, with the accompanying increases in construction costs, some of the Northern Plains States gave consideration to the use of stabilization ponds as the sole treatment process for domestic sewage. The first such installation was constructed at Maddock, North Dakota, in 1949. As a result of experiences here, their popularity grew rapidly until at the present time there are some 75 waste stabilization ponds in the Dakotas, and 140 in the States throughout the Missouri River Drainage Basin.

Mechanism of Purification Process

Several general descriptions of the use of waste stabilization ponds and the mechanisms of sewage purification have appeared in the literature.[1-11] The process is as old as nature itself and is taking place constantly in our streams and lakes. The stabilization process is a mutually beneficial interaction between bacteria and algae. The organic matter in the waste is broken down by bacteria to carbon dioxide, ammonia, and other nutrients. These, with light energy, supply the principal requirements for algal photosynthesis, which liberates excess oxygen to maintain an aerobic system. Without algae, the oxygen supply must come from the atmosphere. In waste stabilization ponds, this method of aeration is insufficient to supply the oxygen demand. Algal photosynthesis is therefore essential to the stabilization process.

An important physical process in the functioning of stabilization ponds is sedimentation of organic matter which may undergo either aerobic or anaerobic decomposition, depending upon the intimacy of contact with the overlying aerobic liquid. Dispersion of these deposits is desirable and is accomplished in the pond by wind action, and to a lesser degree by convection currents. Chemical reactions may also take place which precipitate colloidal or even dissolved solids.

Field Studies

The first stabilization ponds in the Dakotas were installed on a more or less experimental basis. The need for rational design criteria was soon recognized. To evaluate the various factors affecting the stabilization of raw sewage in these ponds, a joint State-Federal field study was planned and carried out on five ponds in the two States during each of the four seasons in 1955, with certain special studies extending through August of 1956. A secondary objective was to develop design criteria having general application elsewhere. The first field study was initiated in January of 1955, at which time all lagoons were heavily covered with ice. The other studies were conducted during the spring, summer, and fall seasons.

Each facility was studied intensively for a three-day period each season, with around-the-clock sampling.

The observations and analyses for each of the four seasonal investigations included: Physical - influent and effluent flows, turbidity, suspended solids, wind velocity and direction, air and pond temperatures, light intensity, structural features, and volume of contents; Biological - plankton and bottom organisms, coliform bacteria (MPN), and special tests; Chemical - dissolved oxygen, biochemical oxygen demand, pH, alkalinity, nitrogen (total, ammonia, nitrite, and nitrate), phosphate (total and ortho), sulfides, and chlorides.

Special soil studies were carried out during the summer to determine the underground movement of water from the ponds and to relate the structure of the soil in the pond bottoms and dikes to percolation. From the standpoint of possible odors, the transition period from ice cover to open water is the critical operating season in the Dakotas. Several installations were inspected routinely during the spring of 1956 in an endeavor to identify factors responsible for the varying rates of recovery from anaerobic conditions existing under ice cover to the aerobic conditions prevailing during the other seasons.

During August of 1956, a mosquito survey was conducted at some 25 installations in the two States to determine the extent of mosquito propagation and what, if any, measures are required for its control.

A summary of these Dakota studies has been reported[12] and a comprehensive report of the survey will soon be available. Table I is a summary of the pertinent data relating to the degree of seasonal purification obtained at the five locations. A review of the data indicates that the degree of purification obtained at all installations studied is quite comparable to that obtained by the conventional complete treatment processes.

During the summers of 1955 and 1956, the Service also assigned an engineer to the Texas State Department of Health to evaluate the data in the files of the Engineering Division on 190 "oxidation" ponds in that State. Unfortunately, limited funds and personnel did not permit carrying out field investigations similar to those in the Dakotas. The analyses of the available data did supply information on the use and application of such facilities in this section of the country. Table II summarizes some of the pertinent data from these studies.

Design Considerations

It is believed the remaining time can best be devoted to discussing some of the more important factors to be considered in the design of such facilities. These may be divided into two general categories, namely (1) uncontrollable factors such as light, temperature, wind, and other climatological characteristics that affect the efficiency of the purification processes and (2) factors such as size, shape, depth, area, loading, inlet and outlet devices, soil composition, site selection, method of operation, etc., that are subject to some control in the engineering design of the structure.

Light

Light is the source of solar energy essential for photosynthesis - the primary source of oxygen in this aerobic stabilization process.

Three important variables require consideration. First, the regional variations in annual solar radiation, which differ with latitude, elevation, and cloud cover, will determine how well a stabilization pond will operate in a given location. Second, the seasonal changes in daily solar radiation will help

to determine the seasonal rates of photosynthesis and the related oxygen production, and may give an indication of the seasonal difficulties to be expected. Third, the penetration of incident light determines how much of the pond volume will participate in oxygen production. This will have a direct bearing on the desirable pond depth.

The geographic and seasonal variations in per cent of possible sunshine for the United States are shown in Fig. I. These data, together with length of day, will give an indication of the solar energy available in any given area. Oswald and Gotaas[11] have also published tabular data showing the probable average values of solar radiation reaching the earth's surface by latitude and month.

The depth of light penetration in stabilization ponds is directly related to algal concentrations and is strikingly less than in most bodies of natural water. Light transmission in three different ponds, having different algal concentrations as indicated by the Chlorophyll A concentration, is shown in Fig. II. The layer absorbing 99% of incident light, called the euphotic zone, is the stratum in which all appreciable photosynthesis occurs. In the Dakota studies, the depth of this layer varied from 2 inches to 27-1/2 inches in the five different ponds in the three open water seasons. During winter months, ice formation reduced the amount of light reaching the liquid to the point where photosynthesis was nil, resulting in anaerobic conditions under continued ice cover.

Oxygen production, at the light intensities prevailing at various depths, was also measured in the Dakota studies. These tests were carried out by measuring the dissolved oxygen change in a pond sample during incubation at selected depths in clear bottles and in other bottles covered with aluminum foil to exclude the light. Typical data from one test (Table III) show that the rate of oxygen production from photosynthesis drops off rapidly with depth, somewhat parallel to the extinction of light. In this case, oxygen production did not equal the demand at depths greater than 24 inches.

The ponds showed great variation in dissolved oxygen during a 24-hour period. Daytime peaks may range from near saturation to several times this value. Normally, during the night, respiratory requirements of the algae, coupled with bacteria and other biota, result in lowering the concentration to less than saturation. In certain ponts generally, and in others only during a period of cloudy weather, nocturnal levels dropped to zero and remained there for from one to several hours. However, objectionable odors did not develop. From these studies it was quite apparent that the oxygen requirements of the biota growing as a result of the sewage nutrients, greatly exceed that of the sewage itself.

Temperature

In field observations, pond temperatures closely followed the air temperatures, with the degree of fluctuation decreasing as the pond depth increased. This stabilizing effect on temperatures may prove beneficial during the summer months. In some of the southwestern installations, it has been reported that high pond temperatures favor the production of blue-green algae which in turn may give rise to objectionable odors in themselves.

On calm days, sharp vertical gradients in temperature, dissolved oxygen, and algal distribution were prevalent even in relatively shallow ponds. On warm calm days, a temperature difference of more than 5° C may exist in a

pond depth of 3-1/2 feet. Such gradients, generally formed before noon, disappear during high winds and after sunset, so that temperature is fairly uniform at such times. The curves shown in Fig. III are typical of the relationship between pond depth and temperature, dissolved oxygen, light intensity, and algal populations as reflected by Chlorophyll A concentration.

The depth of light penetration on all ponds studied was greatest during the summer study, the period of highest water temperature. Algae concentrations were also observed to be less during the summer than during spring and fall.

In the northern areas, long periods of continuous ice coverage prevail, and mixing of pond contents is dependent almost entirely upon density and convection currents. These are not sufficient to disperse the settleable sewage solids throughout the pond. At these low temperatures, bacterial activity is also at a minimum with relatively little biological stabilization occurring for long periods of time. By spring there is a build-up of unstabilized sludge banks immediately around the pond inlets. It is highly desirable that this accumulation be thoroughly dispersed throughout the pond to bring it in intimate contact with an aerobic environment before the temperatures rise in the spring sufficiently to stimulate more intense anaerobic action.

Another effect of ice is to increase the concentration of total solids, organic and inorganic, in the underlying liquid as a result of the physical extrusion of all types of solids in the process of ice formation. The melting ice, of course, affords considerable dilution again in the spring.

Wind

Normally, wave action is considered desirable to provide for surface aeration and mixing of the dissolved oxygen throughout the liquid contents. Under conditions favorable to photosynthesis, however, surface agitation by high winds was observed to lower the degree of dissolved oxygen supersaturation in the top layer of the pond's surface.

In the Dakota studies, the water surface of stabilization ponds was observed to resist wave formation when winds were less than 30 mph. This is apparently due to a reduced surface tension, possibly resulting from the concentration of detergents in the incoming sewage. Even under these conditions, a distinct movement of the water at the surface does occur. This creates counter-currents in the lower depths of the ponds that may act to disperse the settleable solids deposited on the pond bottom. Wind in excess of 30 mph did cause noticeable waves. This turbulence in a shallow pond should disperse the settleable solids through the pond. This more violent turbulence is especially desirable in areas having a period of continuous ice coverage in order to disperse the winter's accumulation of sludge.

On the basis of field observations, it would also appear that wind of sufficient magnitude to cause wave action, might be more important in those ponds handling raw sewage than would be the case in ponds receiving settled sewage. In general, winds of sufficient magnitude to induce wave action are advantageous. The wind velocity required to provide good mixing is believed to be related to pond size. A disadvantage of wave action is in the danger of greater erosion of the shorelines or dikes surrounding the ponds.

Evaporation, Precipitation, Seepage

In order for a stabilization pond to have an overflow, the sum of the sewage flow plus precipitation must be greater than the sum of evaporation plus

seepage through the pond bottom and dikes. In most locations where stabiliza-
tion ponds are now being used, annual evaporation exceeds annual precipitation
by a considerable amount. Under such conditions, the loss of pond contents by
seepage through the soil becomes increasingly important. If this loss is too
great, the depth of liquid in the pond could be lowered to such an extent as to
make the pond inoperative. This situation has prevailed in some localities,
and it has been necessary to treat the pond bottom and dikes to make them
relatively impermeable. In at least one instance, a layer of compacted clay
has been placed on the bottom and dikes to reduce the loss from seepage.
There is some evidence indicating that sewage solids may, in time, reduce
the rate of seepage. Reliable criteria for evaluating the possibility of such a
condition occurring, are not available, however.

Some of the Dakota installations are purposely designed to have no over-
flow. Under such conditions, the water level may be expected to fluctuate in
accordance with the relationship of evaporation and seepage to sewage flow
and precipitation.

For prescribed organic loadings, the rate of inflow per unit of surface
area will be in direct proportion to the degree of pretreatment. Therefore,
pretreatment may be in order where seepage and evaporation are excessive,
or where water conservation is a primary objective.

Area and Loading

Surface area is one of the basic considerations in the design of waste
stabilization ponds. It is customary to express pond loadings in population,
or more preferably, in pounds of BOD per acre of surface area. If aerobic
conditions are to be maintained during all periods of open water, the loadings
will be governed by the oxygen production during periods of minimum algal
activity and photosynthesis. Such a critical period can be expected to prevail
in any location. In the Dakotas, this critical period occurs during the transi-
tion from ice cover to open water. At this time, the contents of the pond are
anaerobic; a large amount of unstabilized organic matter has accumulated
during the winter and algal activity is at a minimum. To prevent possible
nuisance complaints, it is desirable that aerobic conditions be re-established
with a minimum of delay. On the basis of Dakota experience, loadings of
from 15 to 20 lbs. of BOD per acre per day, will result in a minimum re-
covery period in the spring. At other seasons, it appears that aerobic condi-
tions can be maintained with much heavier surface loadings. This statement
is borne out by experience elsewhere, where loadings from two to four times
this figure are not at all unusual. In Texas, even higher loadings are being
applied in some installations with satisfactory results.

During the transition period at those ponds observed in the Dakotas, the
intensity of odors resulting from anaerobic decomposition varied over a wide
range; however, no complaints were filed with either the local or State health
departments. At no time during this period did the pH drop below 7.0.
Normally, the most objectionable gases of anaerobic decomposition are not
produced at pH 7.0 or above.

Studies at the University of California and Texas[11,13,14] have demon-
strated that with appropriate operating controls and facilities, much higher
loadings may be applied to utilize more completely the oxygen producing po-
tential of chlorophyll bearing organisms. Attendant with this increased effi-
ciency, however, are increased operational and maintenance requirements

and costs, as well as additional mechanical equipment, factors of particular importance in small communities.

Depth

On the basis of oxygen production, the optimum depth would appear to be not greater than 2 feet. However, from a practical standpoint, it is believed that this depth varies with the season of the year. In cold climates, when ice thickness may vary from a few inches to over 3 feet, a total depth of 5 feet does not appear unreasonable. In these same locations, our experience indicates that spring recovery proceeds most rapidly in ponds having shallow depths. During the high temperature summer months, a depth of from 4 to 5 feet assists in maintaining more uniform pond temperatures. Shallow depths will permit better mixing and dispersal of settleable matter by wind action; however, a minimum of 2-1/2 feet appears to be necessary to discourage the prolific growth of rooted aquatic plants. On the basis of observations to date, it is believed desirable to provide for varying the operating depth from 2-1/2 to 5 feet.

Shape

Irregular shorelines in raw sewage stabilization ponds should be avoided. Coves, peninsulas, and islands provide protected areas where floating material may accumulate. Under normal operating conditions, ponds are surprisingly free of scum and floating sewage solids except where such protected areas exist. From a hydraulic standpoint, currents within the pond are much less affected by the shape and relative location of inlets and outlets than they are by wind action and temperature. The rapid and almost complete mixing of the pond contents was evidenced by uniformity of analyses on samples collected throughout the pond outside a radius of over 50 feet from the inlet. This condition prevailed in both overflow and non-overflow facilities. This rapid mixing of all except settleable solids was also observed under ice.

Site Selection

Although many stabilization ponds are operating without complaint in close proximity to residential areas, to minimize the possibility of complaints from objectionable odors during the spring break-up, the Dakota State Health Departments suggest that ponds should be located approximately one-half mile from a community and one-fourth mile from the nearest residence. These distances are not too different from those considered desirable in site selection for conventional sewage treatment plants. In areas where aerobic conditions can be maintained throughout the year, the distances may possibly be reduced.

Where possible, the pond site should be located downwind from habitation and where the pond surface will have an unobstructed wind sweep. Consideration must also be given to soil characteristics, proximity of ground water aquifers, and whether gravity flow can be obtained. It should be apparent that it is unnecessary to provide the same degree of hydraulic flexibility in pumping to stabilization ponds as required in pumping to sedimentation tanks. Consequently, the structure, equipment, and controls in lift stations for stabilization ponds can be of a more simple design than for conventional treatment plants.

Dikes

Dikes or embankments should be constructed to facilitate maintenance of weed-free shorelines, be as impervious as possible, and the top width should be adequate to accommodate maintenance vehicles. For insect control, steep side slopes minimize vegetation growth along the shorelines, but flat slopes are desirable to reduce erosion by wave action, a problem that increases with size of pond. Inside slopes commonly recommended, range from 3 to 4 horizontal to 1 vertical. Minimum freeboard should approximate 3 feet. Here also, the size of the pond and the protection against wind action require consideration. Good engineering practice should be observed in providing proper soil compaction in dike construction.

Pond Bottom

The pond bottom should be essentially level and should be free of vegetation when placed in operation. There may be some advantage in providing a slightly deeper area around the inlet to facilitate developing a depth of liquid that will promote algal growth in the early stages of operation. However, this increased depth will be a disadvantage from the standpoint of reducing wind induced currents for dispersal of settleable solids when the pond has reached its regular operating level.

Inlets

In raw sewage stabilization ponds, the inlet should be some distance from the shoreline so that wind from any direction will have a tendency to cause currents to disperse the settleable sewage solids. Center, or near center inlets are commonly employed in the Dakotas with no evidence of short circuiting between inlet and outlet.

The inlet is usually laid on the bottom with a horizontal discharge. Admittedly, the velocity during minimum flow periods through these submerged pipes is extremely low, but no clogging or other troubles have been encountered.

Outlets

For maximum flexibility in operation, the outlet structure should provide for varying the pond operating levels. In the Dakota studies, algal concentrations generally were greater at the surface than at deeper depths. If it is desirable to exclude algae from the effluent, subsurface withdrawals may be desirable.

In northern climates, the overflow structures must be so constructed that ice formation will neither stop the overflow nor damage the structure.

Multiple Ponds

On the basis of observations to date, the flexibility of operation offered by multiple ponds appears to have certain advantages.

With ponds designed to operate in parallel, it is possible to divert the entire flow to one pond when first placing the system in service, thereby reducing the lag period commonly experienced in developing a desirable liquid depth with the attendant weed control problems.

In raw sewage ponds operating in series, the settleable sewage solids will

practically all be deposited in the first cell. Therefore, the loading on this primary pond will be governed by the same criteria required to maintain aerobic conditions in a single pond system. Recirculation from secondary ponds may permit some increase in primary pond loading, but the extent of possible recirculation benefits on loading have not yet been investigated.

Reducing individual pond size, made possible by multiple ponds, will reduce wind effects. This is an advantage from the standpoint of dike erosion, but a possible disadvantage from the standpoint of mixing of pond contents.

Public Health Considerations

Some concern has been expressed relative to public health hazards associated with possible transmission of pathogens from stabilization ponds by insects, rodents, water fowl, and direct contact with the pond or its effluent.

The same personal hygienic practices should be observed around the stabilization ponds as at other sewage treatment plants. Although the bacterial removal as measured by coliform counts (MPN) is very high, the possibility of infection by contact with sewage while undergoing the purification processes must be recognized.

Fencing to exclude livestock from the pond area should be provided, as should the posting of "no-trespassing" signs, and signs indicating the type of facility within the enclosure.

The effluent from properly functioning stabilization ponds is comparable to that from secondary treatment plants and may be discharged in a similar manner.

The potential of insect propagation (especially mosquitoes) is much greater at ponds than at conventional treatment works. Experience in the Dakotas indicates this potentiality can be largely controlled by eliminating emergent vegetation from the pond's surface. Control by the use of larvicides is also possible.

Stabilization ponds are frequented by wildfowl, but the surface area of ponds, in comparison to natural bodies of open water, is relatively insignificant and the per cent of total wildfowl contacting the former would be proportionally small. There is no epidemiological evidence indicating this is a public health hazard.

CONCLUSIONS

The efficacy of stabilization ponds in treating raw sewage in the Missouri Basin States has been demonstrated by experience and confirmed by extensive field investigations.

While considerable research and field investigations are still needed to better define the full effects of various factors on the purification processes involved, the studies to date have established useful design criteria for stabilization ponds in climates similar to that in the Dakotas.

Satisfactory operating experience at many similar facilities in California, Texas, and other southwestern States, has demonstrated the practicability of this method of sewage treatment in a warm and arid climate.

With knowledge of the effects of climate upon stabilization processes, the design criteria applicable to these areas should be adaptable elsewhere. This will make it possible to consider stabilization ponds in the economic and

engineering evaluation of waste treatment methods.

On the basis of raw sewage loadings commonly employed in the Dakotas, it is apparent that required land areas may well preclude the economic use of such facilities in many localities. It may therefore be expected that stabilization ponds will find their greatest applicability in serving small communities where advantages such as lesser construction and maintenance costs and simplicity of operation may be balanced against these increased land requirements.

ACKNOWLEDGMENTS

REFERENCES

1. Caldwell, D. H.
   Sewage Oxidation Ponds - Performance, Operation, and Design. Sew. Wks. Jour., 18: 433-458, 1946.

2. Ludwig, H. R., and Oswald, W. J.
   Role of Algae in Sewage Oxidation Ponds (Symposium on the Role of Ecology in Water Pollution Control). Scientific Monthly, 74: 3-5, 1952.

3. Ludwig, H. F., Oswald, W. J., et al.
   Algae Symbiosis in Oxidation Ponds. I. Growth Characteristics of Euglena gracilis Cultured in Sewage. Sew. and Ind. Wastes, 23: 1337-1355, 1951.

4. Oswald, W. J., Gotaas, H. B., et al.
   Algae Symbiosis in Oxidation Ponds. II. Growth Characteristics of Chlorella pyrenoidosa Cultered in Sewage. Sew. and Ind. Wastes, 25: 26-37, 1953.

5. Oswald, W. J., Gotaas, H. B., et al.
   Algae Symbiosis in Oxidation Ponds. III. Photosynthetic Oxygenation. Sew. and Ind. Wastes, 25: 692-705, 1953.

6. Parker, C. D., Jones, H. L., and Taylor, W. S.
   Purification of Sewage in Lagoons. Sew. and Ind. Wastes, 22: 760-775, 1950.

7. Wennstrom, M.
   Biological Purification of Sewage in Shallow Ponds. Proc. United National Scientific Conference on the Conservation and Utilization of Resources, August 17 - September 6, 1949, at Lake Success, N.Y., pp. 124-127, 1949.

8. Smallhorst, D. F., Walton, B. N., and Meyers, J.
   Design and Operation of Oxidation Ponds. Public Works, 84: (12), pp. 89-90; 111-114, 1953.

9. Van Heuvelen, W., and Svore, J. H.
   Sewage Lagoons in North Dakota. Sew. and Ind. Wastes, 26: 771-776, 1954.

10. Neel, J. K. and Hopkins, G. J.
    Experimental Lagooning of Raw Sewage. Sew. and Ind. Wastes, 28:
    1326-1356, 1956.

11. Oswald, W. J., and Gotaas, H. B.
    Photosynthesis in Sewage Treatment. Proc. Amer. Soc. Civil Eng., 81,
    Separate No. 686, pp. 1-27, 1955.

12. Towne, W. W., Bartsch, A. F., and Davis, W. H.
    Raw Sewage Stabilization Ponds in the Dakotas. Sew. and Ind. Wastes, 29:
    No. 3 (In press), 1957.

13. Gloyna, E. F., and Hermann, E. R.
    Some Design Considerations for Oxidation Ponds. Proc. A.S.C.E., 82,
    Paper 1047, 1956.

14. Oswald, W. J., Gotaas, H. B., Golueke, C. G., and Kellen, W. R.
    Algae in Waste Treatment. Sew. and Ind. Wastes, 29: No. 4 (In press),
    1957.

TABLE I
Operational Data

Dakota Stabilization Ponds

1955

	Kadoka, S.D.		Wall, S.D.		Lemmon, S.D.		Maddock, N.D.		Wishek, N.D.	
Population										
1950 Census	584		556		2,760		741		1,241	
POND										
Date constructed	1953		1951		1951		1949		1952	
Area (Acres)	3.0		8.9		27.1		11.7		7.8	
Ave.Depth (Ft.)	4.4		1.2		5.7		4.0		3.0	
Volume (M.G.)	4.3		3.5		50.4		15.3		7.3	
LOADING										
LbsBOD/acre/day	22.9		7.0		6.8		9.3		13.0	
PE/acre/day*	135		41		40		55		77	
Pop.served/acre	195		62		96		63		160	
							(First Pond)			
Analyses and % Reduction	Under Ice	Open** Water	Under Ice	Open** Water	Under Ice	Open** Water	Under Ice	Open** Water	Under Ice	Open** Water
BOD (ppm)										
Raw	560	380	298	315	400	188	357	237	499	207
Effluent***	22	36	168	41	35	19	83	10	150	32
% Reduction	96.1	90.4	43.6	87.1	91.2	89.6	76.8	95.8	70.0	84.3
Suspended Solids										
Raw (ppm)	1030	334	287	262	370	309	394	255	885	207
Effluent***	124	111	92	556	39	91	49	89	84	156
% Reduction	88.0	66.8	67.9	(+112.2)	89.4	70.5	87.6	65.2	90.5	24.4
MPN										
Max.% Red.	99.9	99.9	96.8	99.9	99.8	99.9	97.4	99.7	99.2	99.8
Min.% Red.	99.9	99.2	83.6	99.1	99.7	59.5	95.9	95.4	97.8	95.9
pH (Effluent)*										
Max.	8.5	9.1	8.2	11.2	8.7	9.7	8.2	9.3	7.7	9.7
Min.	8.2	7.4	7.0	9.1	8.3	8.9	8.0	8.2	7.5	8.4
D.O. (Effl.)*										
Max. (ppm)	0	23.5	0	39.8	6.8	42.0	0	24.2	0	37.8
Min. (ppm)	0	0	0	0	0	2.1	0	0	0	0
CHLORIDE(Effl.)*										
Raw (ppm)	126	144	97	81	214	179	105	139	68	54.0
Effl.(ppm)***	219	165	335	156	200	203	285	184	125	61.5
% Increase	73.8	14.6	245	92.6	(-6.5)	13.4	171	32.4	83.8	13.9

*   Based on 0.17 lbs. BOD per P.E.

**   Entries under open water are average of Spring, Summer and Fall analyses.

***   Installations at Wall, Maddock and Wishek had no effluent;
"effluent" entries for these installations are the average
of analyses for all sample stations within the pond (outside
a radius of 50 feet from the inlet).

TABLE II

Stabilization Ponds

in Texas

(Summary of Statistical Evaluation - 1956)

LOADING	Total Observations	Maximum	Minimum	Median
1950 Population	188	408,442	175	2,366
Population Served	119	500,000	300	1,992
Number of Cells	162	20	1	1+
Total Area	151	850	0.04	4.2
BOD (Lbs./acre/day)	34	2,280	2	32.5

OPERATION	Total Number Reported	Yes	No
Pretreatment	182	174*	8
Recirculation	25	8	17
Effluent Discharged	175	154**	21
Mosquito Problems	26	6	20
Odor Complaints	69	9	60
Clear Effluent	44	38	6
Fish Present	67	31	36
Ducks Use Pond	67	54	13

* 134 Primary; 40 Secondary.

** 80 to streams; 74 to irrigation.

Table III

LEMON, SOUTH DAKOTA

Oxygen Production at Different Depths
During a Five-Hour Period
August 12, 1955

% Surface Light	Light Intensity Approx. F.C.	Depth Inches	D.O. change, P.P.m		Oxygen Production Per Hour P.P.m.	Respiration Per Hour P.P.m.
			Light Bottles	Dark Bottles		
19.0	1050	10	+12.6	-2.1	2.9	0.4
3.1	167	24	0.0	-2.1	0.4	0.4
0.5	27	38	-1.4	-2.0	0.1	0.4
0.07	3.8	53	-1.6	-1.8	0.04	0.4

Determinations were made in triplicate.

NORMAL ANNUAL SUNSHINE (% OF POSSIBLE)

NORMAL SUMMER SUNSHINE (% OF POSSIBLE)

NORMAL WINTER SUNSHINE (% OF POSSIBLE)

Figure I

RELATION OF LIGHT PENETRATION TO
CONCENTRATION OF CHLOROPHYLL A (p.p.m.)

Figure II

VERTICAL GRADIENTS FORMED ON CALM BRIGHT DAYS
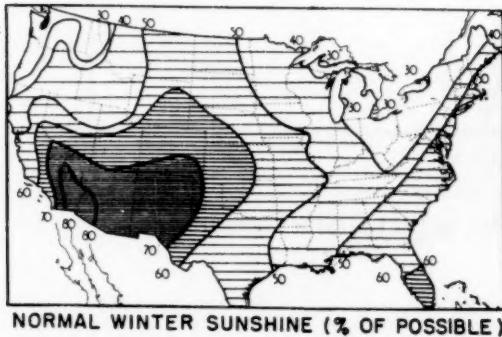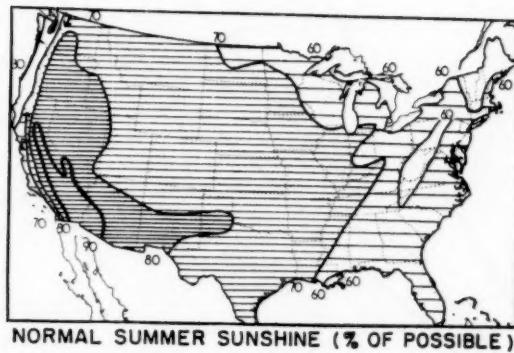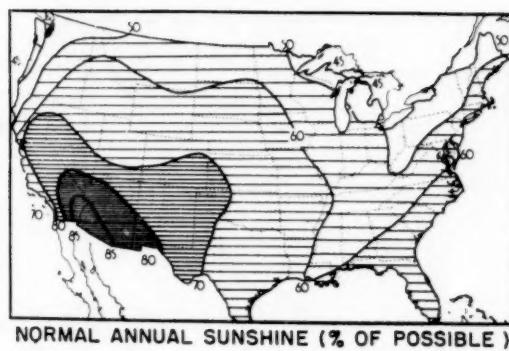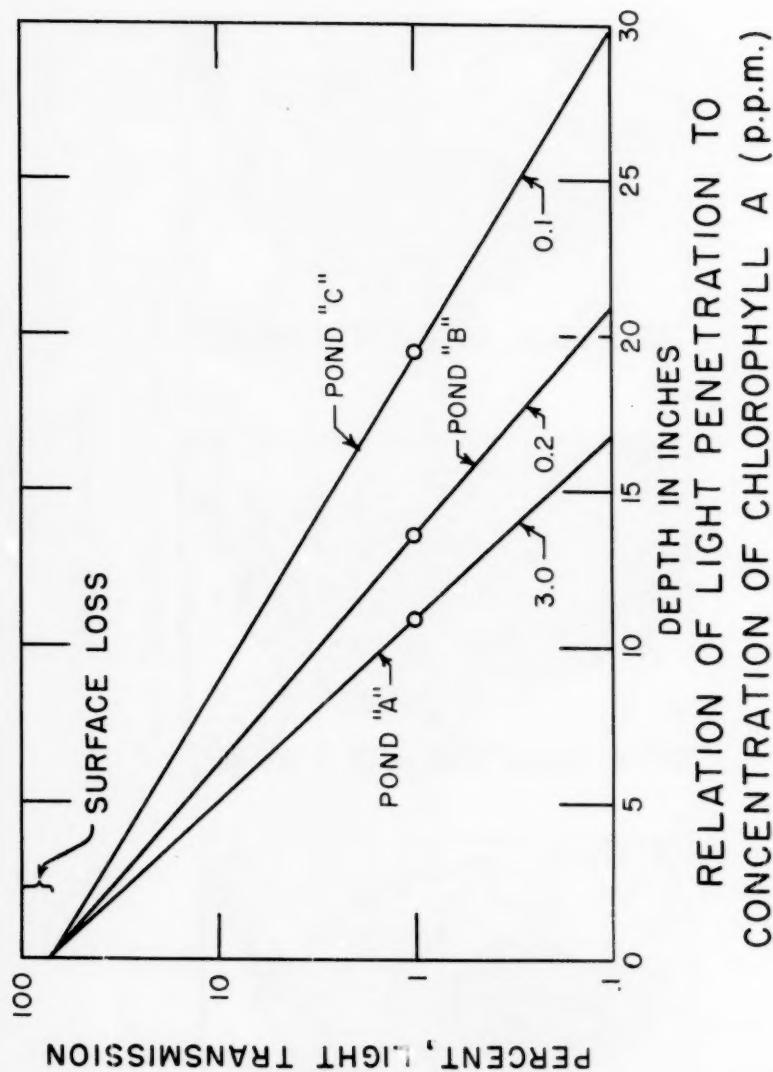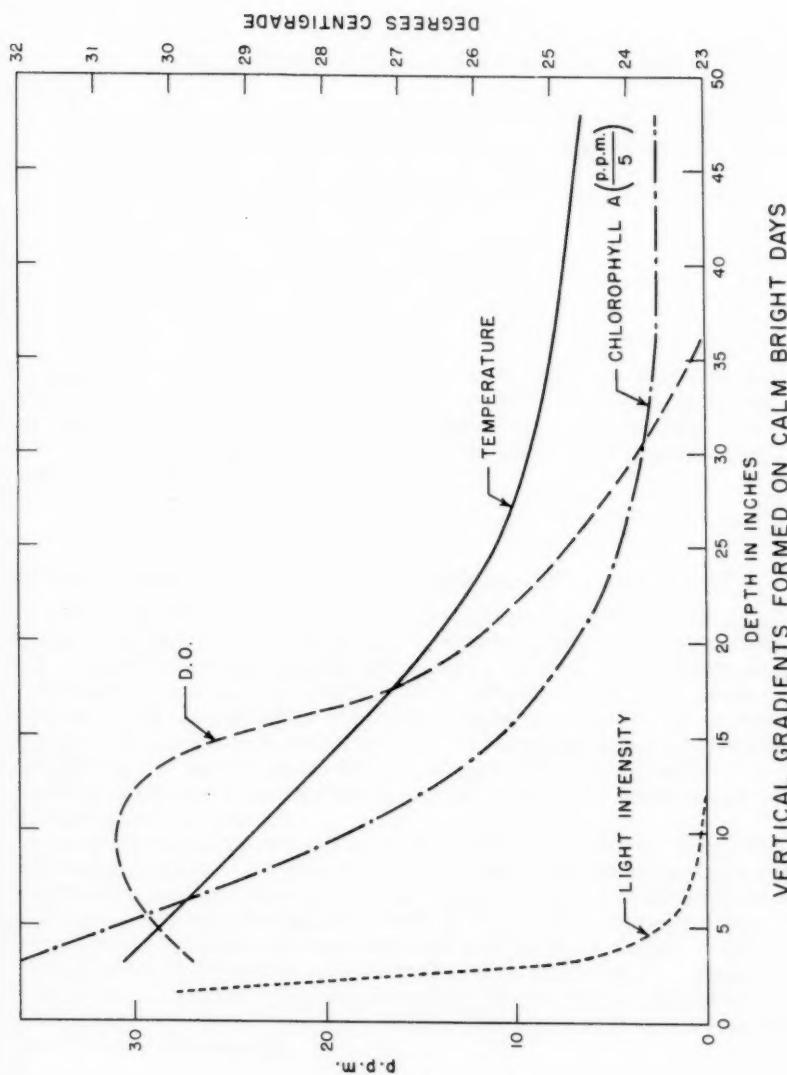
Figure III

Journal of the
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

THE USPHS STREAM POLLUTION ABATEMENT PROGRAM [a]

Lewis A. Young, M. ASCE[*]
(Proc. Paper 1338)

The paper discusses reasons why engineers should be interested in stream pollution abatement, the problems of pollution and the State and Federal programs that are being developed to correct them. The new Federal Water Pollution Control Law is discussed. The importance of protecting our water resources is stressed.

Why should engineers be interested in stream pollution abatement?

The problems of pollution are not new. They are as old as civilization itself. It is recorded that the Kingdom of Nebuchadnezzer was destroyed by sin, corruption and the worship of false gods. These had a definite assist from engineers blind to everything but the efficiency of their irrigation ditches, from agriculturists and economists blind to everything but increasing crop production and profits, and from a blindness by all to the need for preserving the water supply. There may be a difference of opinion as to which was the major factor contributing to its downfall, but it is agreed that Babylon destroyed itself.

Since the beginning of time man's goal has been survival. In his haste he has made mistakes. Whenever his neglect destroyed his water supply the destruction was complete and he was forced to migrate to virgin country.

When this Nation was young the effects of pollution on water resources were usually ignored. The abundance of water of good quality, in most sections of the country, encouraged wasteful usage without full realization of the true worth of this most valuable resource. There was not then the keen competition for water. Pollution did not have a telling effect on this stage of our Nation's development.

The present way of life demands increasing amounts of water. The world's water supply is a fixed quantity that cycles endlessly. Misuse of this resource can place a ceiling on the development of this country, stifling its progress. Good water is a necessity. It is essential to development, progress and life. Its availability will depend not only upon nature's laws but also upon our engineering capabilities. The control of water quality by pollution abatement is a prerequisite to the maximum utilization of water resources.

What are the problems of pollution?

The fertile lands, extensive forests and the abundance of mineral wealth are gifts of nature with which people have built a civilization unmatched in history. The production of lands, forests, mines and oil fields have made possible a growth, development and industrialization which has never been equalled. This could not have been possible without one vital resource, "WATER."

The growth of this Nation has been rapid. In the last century and a half people have settled and developed the lands from the Appalachian Mountains to the Pacific. Large and small cities have developed water supplies furnishing adequate quantities of pure water for domestic purposes. Large and small dams have been constructed to provide for flood control, navigation, hydroelectric power and irrigation.

In the haste to achieve greater development, forests have been destroyed, leaving barren, denuded lands. Land has been overplowed and overgrazed. Soil erosion has increased, silting up reservoirs, increasing the damage of floods and muddying streams with precious top soil. The discharge of wastes has also polluted many streams.

Pollution is the addition of any substance to water that interferes with any of the legitimate uses of water or is detrimental or potentially detrimental to animal, plant, or aquatic life. The degree of pollution can be classified as follows:

1. Natural pollution - no use made of the resources by man - the water picks up impurities from the air and the earth's cover, its soils and minerals.
2. Permissible pollution - good abatement practices and planned use of the water resources.
3. Allowable limited pollution - reasonable overloading of receiving stream which reduces the full usefulness of the water resources for a limited zone without damage to other beneficial water uses.
4. Excessive pollution - misuse - destruction of the water resource.

Water, being a universal diluent, is rarely found in its pure state. It is inevitable that the quality of water will be altered when it is used. Almost everything man does with water causes some deterioration in its quality. The pollution of water is a natural result of water use.

The natural activity of water provides some purification of organic wastes. Any natural body of water has an organic waste assimilating capacity. The effects of inorganic wastes are generally accumulative. Both natural and man-made impurities tend to increase in the water. The value of the water resources is limited by their usability (quality) as well as quantity. Every water user has a right to his fair share of the stream's natural waste-assimilating capacity. This can only be assured by cooperative planning in

the development of the resources of a watershed.

One of the important water uses is the carrying away of waste materials. There are many kinds of wastes. Some can be handled in limited amounts without damage to the resource. Treatment will permit the satisfactory handling of other types of wastes if there is adequate dilution. Some inorganic wastes of industry, however, reduce the effectiveness of treatment processes applicable to organic wastes and must be handled separately. Some industrial wastes are toxic and otherwise harmful. Untreated wastes dumped into water-courses or permitted to find their way into underground aquifers may render the water unsuitable for use. These are problems of pollution.

Why a Federal Program?

The people have a right to decide on what water uses will be given priority. Even men of good will, however, sometimes find it difficult to agree on water usage. Among other things a State program is needed to evaluate the water resource. At a recent hearing for the purpose of classifying waters of one of the larger streams on the Atlantic Seaboard, the importance that the river had played in the development of the area was revealed.

The differences in attitude of those attending the hearing was very marked. One paper company offered full cooperation. The other asked that their sec-tion of the stream be classified so as to permit the discharge of their wastes without treatment.

Before the turn of the century this stream was noted for an abundance of fishes. A day's commercial catch near the mouth of the stream often num-bered many thousand fish. Fishing varied with the natural conditions of the stream.

A small town at the foot of the rapids just downstream from where the river cascades from the Piedmont Plateau onto the upper part of the Coastal Plain was proudly known as the rock fish capital of the world. This section of the stream was chosen by the striped bass as their spawning grounds. It is believed that in the rapids of the river have been spawned all the striped bass for a large section of the Atlantic Coast. The sport fisheries alone are now valued at more than a million dollars a year and the value of commercial fisheries undoubtedly exceeds this amount.

In 1909 a mill to produce the first kraft pulp to be made in the United States was constructed on the bank of the river. The site chosen for the mill was near the fall-line where there was water power, an adequate supply of wood and an abundant supply of water. Natural resources such as these play a major role in the selection of a site for any industry. No pulp and paper mill could competitively exist without them.

The industrialization of the valley did not stop with one paper mill. Soon the flow of the river was harnessed by the construction of a hydroelectric plant and the power generated attracted still more industries to the area. The first hydroelectric plant was small and did not fully utilize the potential af-forded by the river's flow. A series of larger dams were planned. Two have been built and the stream flow is now regulated by peaking operations adding to the difficulty of working out an equitable solution for all existing water uses and precluding full development of the area.

The industrialization of the valley is no longer limited to the area near the fall-line. Upstream there are other hydroelectric dams, textile plants and other industries. At the fall-line there are textile plants and other industries

as well as the original paper mill. The industrial development near the mouth
of the river includes a second large pulp and paper company. This mill pro-
duces sanitary board for the manufacture of milk cartons and other food con-
tainers. If it were possible to stand all the milk cartons they produce during
one year end on end the column of milk cartons would reach half way to the
moon.

Industrialization of the valley has afforded continuous employment for a
large number of workers. Money has been spent locally for the purchasing
of pulp wood, raw materials and operating supplies. Industrialization has
brought prosperity to the area. It has also brought pollution to the streams.

All of the various types of development add their pollution. During late
summer, water stagnates in the depths of hydroelectric reservoirs and the
discharged water is without oxygen. The wastes from the industrial and
municipal sewers contribute an additional pollutional load and delay the
stream's recovery. The fishery is threatened both by the pool quality of the
water and by the regulation of the flow.

In a cooperative study State and Federal Agencies and industrial and
municipal entities are seeking an equitable solution to the problem. The State
agency is acting under a law which gives it the authority to classify the
streams based on data showing the potential of the resource. It is obvious
that a law will not make more water available but a good law properly applied
can assure full utilization of this resource. A good stream pollution abate-
ment program is a service to industry as well as to the people. The States
which have adequate programs are developing their resources in an orderly
fashion.

The Federal program is planned to work with - not take over the State
programs. It supplements State activities, without duplication, by furnishing
essential specialized services. The Federal program strengthens the State
programs, and aids in the conservation of the total resource.

What is Public Law 660?

The Federal Water Pollution Control Program started with the passage of
Public Law 845 of the 80th Congress. A new law based on the experience
gained through operations since 1949 was enacted in 1956 as the Federal
Water Pollution Control Act, Public Law 660 of the 84th Congress. It con-
tains added authority for research, training, collection of basic data and
grants for State water pollution control program expansion and the construc-
tion of treatment works, all of which will strengthen the State water pollution
control activities and will focus National attention on pollution problems and
the requirements for their correction.

Section 1. Declaration of Policy.

In its declaration of policy the new law reaffirms the policy of Congress to
recognize, preserve and protect the primary responsibility and rights of the
States in preventing and controlling water pollution. These are not idle words
but represent the long-time policy of the Public Health Service and the Con-
gress. At the same time the legislation recognizes a definite Federal role in
the water pollution control field in research, technical and financial support,
and concern with interstate pollution problems. Other provisions of the Act
reflect this policy and place the State water pollution control agencies in key
positions.

Section 2. Comprehensive Programs for Water Pollution Control

This section of the Act directs the Surgeon General, after careful investigation and in cooperation with interested agencies to develop comprehensive programs for the control of pollution, giving regard to all water uses. Such programs would assure water for our public water supplies, propagation of fish, other aquatic life and wildlife, recreational purposes, and agricultural, industrial, and other legitimate uses.

Section 3. Interstate Cooperation and Uniform Laws

This is a continuation of the authority contained in earlier legislation directing the Surgeon General to encourage cooperative activities, improved legislation and the development of compacts between States for the prevention and control of water pollution.

Section 4. Research, Investigations, Training and Information

This section adds new and important authority in the broad technical field. The research program envisioned by this section is designed to bring to bear on the pollution problem available untapped research potentialities. In addition to research performed by the Public Health Service at its Sanitary Engineering Center in Cincinnati, the Act authorizes research by contract and research grants to universities and research centers. The section also includes important authority for research fellowships and for training not only personnel of public agencies, but other persons with suitable qualifications. In this manner the supply and competency of water supply and water pollution control personnel can be improved and more rapid local application of research findings will be possible.

The recommendations of the Presidential Advisory Committee on Water Resources Policy in its report of January 17, 1956, placed great stress on the need to collect, analyze, and disseminate basic data of all kinds, including water pollution data. With particular reference to the matter of water quality, the report states that "compared to other basic data programs, the current program for measurement and study of chemical and biological water quality is particularly deficient and present expenditures should be tripled over a period of five years." The House Public Works Committee believed there was a need to implement the recommendations of the Presidential Advisory Committee and consequently inserted in Section 4 of the Act the provision authorizing the collection and dissemination of basic data. At present we are developing a three-phase program to be carried out in cooperation with State water pollution control agencies and other State and Federal agencies: (1) a national water quality basic data program related to sewage and industrial waste pollution, (2) a complete and current national inventory of water, sewage and industrial waste facilities, and (3) a detailed basic data program related to the economics of water supply and pollution control.

During the current fiscal year there is an appropriation sufficient to explore in a small way a system for basic data collection and analysis. This period is being devoted to a determination of the kinds of basic data most needed and to discussions with State and Federal agencies as to how this need can best be met.

Section 5. Grants for Water Pollution Control Programs

This section broadens the program grant authority contained in the previous

legislation, and increases the amount of the authorization to $3,000,000 per
year for a period of five years. A sum of $2,000,000 was appropriated for
fiscal 1957. Grant funds are intended to cover a portion of the cost of carry-
ing on approved State plans; the amount of the grant can vary from 33-1/3 to
66-2/3% of the program costs. Allotments to the several States are made on
the basis of population, extent of pollution problem, and financial need of the
respective States. Grants are not intended to replace State funds for water
pollution control but rather to demonstrate to States what can be done through
greater State support of these programs. Use of Federal grants for this pur-
pose has proved effective in other fields and should assist the States in ex-
panded programs to discharge their primary responsibility in the water pollu-
tion control field.

Section 6. Grants for Construction

The provision of the Act authorizing grants for construction of sewage
treatment works has created by far the greatest interest and has carried the
greatest appropriation authority—fifty million dollars a year, to a total not to
exceed $500,000,000. For fiscal year 1957 the full $50,000,000 was appropri-
ated. In approving the legislation, the President pointed out that with respect
to construction grants, the bill went beyond the recommendations of the
Administration. He further urged that "no community with sufficient re-
sources to construct a needed sewage treatment project without Federal aid,
postpone that construction simply because of the prospect of a Federal grant.
It should be clearly understood that Federal aid will not be available to all
communities and, with respect to any one project, the Federal funds are
limited in amount under the provisions of the bill."

Grants are authorized to be made to any State, municipality, or inter-
municipal or interstate agency. The term municipality is defined to include
city, town, borough, parish, district, or other body created by law and having
jurisdiction over disposal of sewage and other wastes. Grants are made for
"construction" which is defined to include preliminary planning, investigation,
studies, surveys, designs, plans, and other action necessary to the erection,
building, acquisition, alteration, remodeling, improvement or extension of
treatment works and the inspection and supervision of the construction of
treatment works. The costs of acquiring project sites and easements are not
eligible for Federal participation. Work covered by contracts let prior to
July 31, 1956, the date of the appropriation approval, and work done prior to
approval of a grant application are not eligible for Federal participation.

Certain action on grant applications is required of the State water pollution
control agency before the Public Health Service can make a grant offer to a
municipality; (1) the project must be approved by the State agency; (2) it must
be stated to be in conformity with the State's water pollution control plan; and
(3) it must be certified by the State as entitled to priority over other eligible
projects on the basis of both financial and water pollution control needs. The
procedures, as we envision them, are entirely flexible depending upon the de-
sires of the State water pollution control agency which plays such an important
part in project selection and other administrative aspects. In general, an ap-
plicant will submit his application to the State for declaration that it conforms
to the State plan, after which the application will be referred to the Public
Health Service regional office for a determination of its conformance with the
various Federal requirements of the Act. However, the State water pollution
control agency might take all three actions, State plan conformity, project

approval, and priority certification before forwarding the application to the
Public Health Service regional office.

The factors which the Public Health Service must consider in reviewing a
Federal grant application are:

1) it must be included in a comprehensive water pollution control program
   developed by the Public Health Service;
2) the Applicant must agree to pay the remaining cost;
3) the Applicant must make provision for insuring proper and efficient
   operation and maintenance of the project;
4) the Surgeon General is required to give consideration to the public bene-
   fits to be derived from the project, the relation of the ultimate cost of
   construction and maintenance to the public interest and public necessity,
   and the propriety of Federal aid in its construction.

When a project has been determined to meet the Federal requirements
under the Act the application will be referred back to the State water pollution
control agency for certification of the project's priority over other eligible
projects. The Public Health Service is then in a position to make an offer of
a grant to the Applicant.

The Act provides for an allotment to each State based 50 percent on popula-
tion and 50 percent in inverse ratio of the per capita income. There is no
provision in the Act for reallocation of unused funds. At least 50 percent of
the funds appropriated for each fiscal year must be used for projects serving
municipalities with populations of 125,000 or less. The administration of the
Act has been set up on a decentralized basis, with authority for reviewing ap-
plications, approving projects and certifying payments during construction,
delegated to the regional offices.

The first applications for construction grants were approved December 5,
1956, for sewage treatment works to serve Meridian, Mississippi, and
Higginsville, Missouri. These approvals were made a little over four months
after Congress provided the first appropriation for this purpose under authori-
ty of the Federal Water Pollution Control Act. On February 1, 1957, the
Atlanta Regional Office had received 64 applications from the six States that
we serve.

Section 7. Water Pollution Control Advisory Board

As in previous legislation, Public Law 660 provides for a Water Pollution
Control Advisory Board, this board to consist of ten members including the
chairman. The chairman is the Surgeon General or a sanitary engineer of-
ficer designated by him and he is the only Federal representative on the
board. Other members are appointed by the President from representatives
of State, interstate, and local agencies, public and private interests, agencies,
organizations or groups, and experts having an interest in water pollution
control. The Congress in establishing the Advisory Board recognized the
need for consultation with other Federal agencies but pointed out that this
consultation is available without membership on the Advisory Board. Field
inter-agency committees provide one method of consultation as does the main
Inter-Agency Committee on Water Resources. Other methods of securing
consultations with Federal agencies will no doubt be considered by the
Advisory Board. The President made public his appointments to the Board
on November 9, 1956. Mr. Milton P. Adams, Executive Secretary of the
Michigan Water Resources Commission, a member of ASCE, was among those
appointed.

Section 8. Enforcement Measures Against Pollution of Interstate Waters

The enforcement measures against interstate pollution have been revised in a number of respects. The House Committee on Public Works, in House Report 2190, 84th Congress states that the "procedures constitute a reasonable balance between the primary rights of the States to control water pollution within their boundaries and the rights of States affected by pollution from another State to have available to them a practicable remedy." One important change is that the hearing is advanced to a point early in the action but still only after there has been every effort to correct the situation through discussions, conferences, and mutual cooperation. A second revision is that enforcement can be initiated through court action either with the consent of the discharging State or at the request of the affected State.

In considering the use of the authority of the Federal courts on cases of interstate pollution, one cannot help agreeing with the Supreme Court of the United States in the 1921 suit of the State of New York against the State of New Jersey relative to the pollution of New York Bay. The court stated that "we cannot withhold the suggestion, inspired by the consideration of this case, that the grave problem of sewage disposal presented by the large and growing population living on the shores of New York Bay is one more likely to be wisely solved by cooperative study and by conference and mutual concession on the part of the representatives of the States so vitally interested in it than by proceedings in any court however constituted." This opinion clearly distinguishes between the values of cooperation and legal processes in relation to pollution abatement. One cannot legislate clean water but legal authority is often needed to permit the development of a cooperative program which will result in pollution abatement.

Section 9. Cooperation to Control Pollution from Federal Installations

The thought that the Federal Government should, by example, show the way in correcting pollution has been reflected in the past primarily through the machinery of an Executive Order. Public Law 660, for the first time, identifies the Department of Health, Education, and Welfare as cooperating in the effort to correct pollution from Federal installations. Activities have been devoted this year to making preliminary arrangements and planning. However, an effort will be made to assist in any situation where problems arise concerning Federal installations.

How can water resources be protected?

The Public Health Service cooperates with other Federal agencies and with the States in determining the effects of water resources developments on existing and potential water uses. The Arkansas-White-Red River Basins Inter-agency Committee, made up of the Corps of Engineers, Department of the Army, Department of the Interior, Department of Agriculture, Department of Commerce, Department of Labor, Department of Health, Education and Welfare, and the Federal Power Commission, is working with State agencies and other interested groups in the development of a comprehensive plan for the entire drainage area of these three tributaries to the Mississippi River. They are collecting data needed in planning for maximum utilization of the water resources of the area with equitable distribution for all types of water uses.

The resources of the stream can best be safe-guarded by planned use. Unlike most natural resources a stream can be utilized by this generation yet passed onto future generations still unexhausted and undepleted. This is possible since the water of the earth is in a continuous cycle. As a vapor, water is lifted from the sea to form clouds that are condensed to fall as rain on the land and return to the sea.

That percentage of rain which does not evaporate back to the sky, transpire from vegetation, or seep temporarily into aquifers where it is stored as ground water, runs off the land forming streams, lakes, and rivers. Much of this water is lost since it returns to the sea as flood water.

The water resource is only that small percentage of the total rain that falls which is available for man's use. Man must plan so as to have adequate water of good quality for all of his needs. It is to be hoped that the engineers or others who do the planning will weigh the total values regardless of their specialties. Modern living demands more water for domestic purposes. New technological changes require increasing quantities of industrial process water. The public must be made to realize the gravity of the problem.

Water resources must be prudently used. There is a need to store additional flood waters to provide for consumptive use and periods of drought. Adequate treatment of all wastes is required to assure re-use and afford maximum utilization of the resource.

This nation's future depends upon the wisdom with which its water resources are developed. The importance of water pollution control in the planning and the development of the total resource cannot be over-emphasized.

Journal of the
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

CONTENTS

DISCUSSION
(Proc. Paper 1349)

Page

Discussion of
"SOME ENGINEERING ASPECTS OF HIGH-RATE COMPOSTING"

by John R. Snell
(Proc. Paper 1178)

CASIMIR A. ROGUS.[1]—Many sporadic studies have been made on composting garbage (food wastes), but only a few on composting refuse (mixture of garbage, rubbish and ashes). Dr. Snell's paper documents the research made at Michigan State University, under his direction, on high-rate composting of municipal refuse. It is a valuable contribution and should help advance the development of a rapid, practical and economic composting system. The long range application of this method of refuse disposal appears promising—particularly because of its conservation appeal. At this stage however, the construction of full scale (100 ton per day or better) composting plants appears premature and fraught with too many uncertainties to warrant investment of substantial municipal funds or the replacement of proven alternate methods of refuse disposal. A few comments relative to the practical aspects of this problem may help clarify the present confusing claims and thus promote the needed further development and future usage.

Successful composting of solid organic wastes is unquestionably achievable. Its use at food handling, packaging and processing plants should be attractive. On the other hand, the processing of unsegregated municipal refuse—an ever-varying mixture of garbage, rubbish and ashes—poses still unsolved problems of design and operation and introduces a high cost element. It must be noted that large scale segregation of refuse at the source, through multiple collections, is neither practicle nor economical.

The economic advantage of refuse disposal by composting, as compared with other competitive methods, must stand on its own merits without tie-ins to the questionable revenues from the reclamation of salvageable materials or from the marketing of a fertilizer end product. Economic analyses of alternate disposal methods is based on direct, dependable cost factors—they do not take into consideration, except as secondary untangible benefits, such potentials as land reclamation; salvage of metals, paper or rags; manufacture of glycerins or alcohols. These, although at times realizable, have insufficient practical dependability to be considered in evaluating the merits of a given process. Historical experience with the deceptive revenues from the now obsolete rendering and reduction processes supports this stand.

The development of practical composting—a costly and time consuming procedure—cannot be left to private industry and to risk capital. Continuity and objectivity can be assured only thru government subsidies. Such subsidies would seem, at this time, to be inconsistent with the present problems of agricultural over-production. Still, from a long range point of view, the modest cost involved is justifiable against the time and circumstance of reclaiming under-nourished soils.

To be acceptable for municipal use, refuse composting should be:

1. Director of Eng., Dept. of Sanitation, City of New York, N. Y.

1. Universally Applicable—it should handle and process "as collected" refuse with a minimum of separation required at the source. The process must be readily adaptable to the ever-changing character and composition of refuse.

2. Dependability—Breakdown of disposal operations requiring plant shutdowns or perhaps creating nuisances cannot be tolerated. Maintenance and repairs should be of the minimum.

3. Competition—Its costs, including amortization, should be comparable to alternate acceptable methods. It should be noted that modern incinerator costs (for large scale operations) are approaching those of sanitary landfills. The costs should be complete—including disposal of non-compostables and the treatment of liquid wastes. Only direct, realizable benefits should be considered.

4. Nuisance-Free—The control of rodents, insects, odors and air pollutants should be at least equal to alternate methods of disposal.

5. Centrally located to tributary collection areas—Trucking costs which are disturbingly high should be held to the minimum.

6. Rapid—To reduce costly land acquisition.

7. Independent of weather and climate—Year round uniform performance is essential.

8. Marketing—As a matter of policy most municipalities avoid getting involved in the business of promoting and selling by-products.

Present promotional activities lack dependable experience and generally overlook many of these basic items. Too often when confronted with them and particularly when the capital risk and operational responsibility is directed at the promoters, selling pressure abates and promotional interests wane—top evidence of todays insufficient development for practical application of high-rate composting of municipal refuse.

CONCLUSIONS

1. Further extensive research on composting of municipal refuse should be encouraged as part of a long range program for the conservation of natural resources.

2. Such research, including development studies through construction of a full scale composting plant, should be subsidized by and should be the responsibility of a federal agency.

3. An acceptable plant for composting municipal refuse should be competitive with other modern disposal methods both as to costs and as to nuisance-free operations—all without tie-ins to unproven and undependable benefits of the salvage and sale of by-products.

Discussion of
"WRITING ENGINEERING SPECIFICATIONS—FOR QUALITY, NOT PRICE"

by Morris M. Cohn
(Proc. Paper 1179)

JUDSON P. ELSTON,* M. ASCE.—This paper is a step in the direction to-
ward improvement of engineering and supply specifications. As there is a
need to strive toward the elimination, insofar as possible, of the expressions
"as directed," "as determined," "the final decision will be made by the con-
tracting officer or Engineer," and others equally as vague, so should we
strive to define the quality of materials, equipment and supplies to reduce the
need for the expression "or equal." There would seem, however, to be an
under current or overtone of dissatisfaction or unhappiness with competitive
bidding as called for in government specifications and in most public works
specs regardless of the origin of the owner and his engineer. Granted that
no work of man may be entirely perfect in this world, there is also every
indication that we as engineers and our fellow men as owners are constantly
striving for and accomplishing improvement in our work and in the end pro-
duct of our work.

The writer is not too sure just what the point is that the author is attempt-
ing to drive home when he says "The question of getting quality in private
engineering projects is left to more academic evaluation because there has
been, unfortunately, some modicum of truth in the expressed view that private
purchasers buy by choice while governmental agencies buy by chance. Let
this be said! As many private specifications have been read and worked with
as governmental ones that used the expression ". . . shall be the equivalent to
that manufactured by the (Joe Bloke Company) or equal." It was not entirely
clear in reading through this paper just what the author had in mind or was
getting at in mentioning the possibility of the elimination of competitive bid-
ding. Perhaps he is thinking that any owners who decide to do away with com-
petitive bidding should direct their engineers to utilize some supposedly un-
biased technical information to specify design, material and fabrication of
equipment, fixtures and the like.

It is difficult to evaluate the reasoning behind the thought that by making an
award to the lowest responsible bidder, the engineer and/or owner is auto-
matically defeating the purpose of competitive bidding by overstressing
price" and underemphasizing "value." A little further on the author says that
the rigidity of any law which demands open government buying openly arrived
at defeats good governmental purchasing. The writer is inclined to take ex-
ception to this remark. It is strongly suspected that knowing the money avail-
able to make a purchase, the quality and type of purchase required that a
governmental specification will secure a product of "as equal a value" as the
private purchasers' specification. In fact, it would be a good bet that under
"open" competitive bidding, quality and money available being the same, the

*   Asst. to Constr. Mgr., Power Area, Uhl, Hall & Rich, Engrs., St.
    Lawrence Power Project, Massena, N. Y.

government buyer would get more quality per dollar than the purchaser who did not utilize "open" bidding. On the presumption that the writer is speaking only of sanitary engineering processes, equipment and materials, the writer would suggest that the names of three reputable manufacturers of quality products, all of whom meet the design requirements, be mentioned by name of product and manufacturer or equal in the specification. The bidding would still be "open" and "competitive" and open to any other manufacturer who could prove to the engineer that his product was the "or equal." The burden of the proof must be on the manufacturer to meet any quality standard established by the engineer and provide proof that his product is equal or better, if necessary. And all of this under open competitive bidding. The engineer should still have the prerogative to take the low bid or the lowest bid whose product met the standards required. And on this point, it is suspected that the author and the writer are in complete agreement. That is, that the owner or his engineer should not be required by law to take the lowest bid unless conclusive evidence exists that the producer and his product meet all the requirements and standards deemed necessary, and established in the specifications.

Engineering New-Record of May 9 editorially comments on the "or equal" clause. The writer is inclined to agree that the proposal of the Building Research Institute be given serious study by the engineering profession.

In conclusion, there is complete agreement with the author that specification writing and the design requirements of engineers must be so improved, the indefiniteness, the vagueness, the arbitrariness reduced and eliminated as to achieve the highest possible quality of product and workmanship at the lowest possible price. In this connection, the writer feels that only through open competitive bidding openly arrived at can we expect to continue and to improve the high standards of living in which the engineering profession plays such a vital role.

DIVISION ACTIVITIES
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

NEWS

August, 1957

SED EXECUTIVE COMMITTEE MEETS AT OKLAHOMA CITY

(Editor's Note: It is regretted that time problems are such that news items cannot be more current but it is presumed that you want the information even if it is a little old.)

The Executive Committee of the Sanitary Engineering Division of ASCE met in Oklahoma City on April 11 to transact the business of the Division. Messrs. Richard Hazen, Chairman; Richard Kennedy, Vice Chairman; Roy Morton; Ray Lawrence; A.D. Caster, Secretary; Howard Peckworth, Board Representative; and Don P. Reynolds, Assistant to the Secretary of ASCE were present.

Actions of the Committee of interest to the membership are as follows:

1. A recommendation was made that the Joint Committee for the Advancement of Sanitary Engineering proceed independently of the American Sanitary Engineering Intersociety Board, and a resolution was passed as follows:

    AGREED, that the functions of the Joint Committee for Advancement of Sanitary Engineering, as defined, and, the function of the American Sanitary Engineering Intersociety Board, as defined, are both so important to the profession that each should proceed with its own work, without responsibility to the other. Members of the Board and the Committee shall be informed of this veiwpoint of SED by the Secretary of SED.

2. B. A. Poole was appointed to the Joint Committee for the Advancement of Sanitary Engineering for the following year, and a recommendation was made that Richard Hazen be appointed to the American Sanitary Engineering Intersociety Board.

3. A discussion was held on how Sessions Program coordination could be accomplished. It was decided that the present Program Committee should be abandoned and a new five member Committee be formed—three of which would be the Steering Committee setting forth the type of program, and two members of the Committee would be temporary members serving as local chairman.

    It was also suggested that one program be promoted on Nuclear Energy, three sessions long with twelve papers.

4. The Sanitary Engineering Division accepted the invitation of the American Institute of Chemical Engineers, to have a representative on the Chemical Engineers for the Nuclear Field, N5 Committee, and Roy Morton, Past Chairman, was appointed to be the representative.

5. Directed that the Secretary write a letter to the Committees on the preparation of the Manuals requesting the status of their Manual, the need of their Manual, if Editors are needed, and the probable final draft date. The Manual on Sanitary and Storm Sewers; the Manual on Design of Sewage Treatment Works; and the Manual on Sanitary Landfill are presently under preparation.

6. Directed that the Secretary send a letter to all Committee Chairmen suggesting that they drop those who fail to work from the Committees and to suggest individuals to replace dropped members.

7. Discussed the selection of an individual to replace Ross McKinney who resigned as Chairman of the Publications Committee.

SANITARY ENGINEERING AT NORTHWESTERN UNIVERSITY

The elements of sanitary engineering have been taught for a number of years at Northwestern University as a part of the undergraduate program in Civil Engineering. After receipt of the Murphy endowment some fifteen years ago, the Master's degree program was initiated, and in the last two years candidates have entered the Ph. D. program.

The graduate program in civil engineering which has included the traditional fields of civil engineering (structures, soil mechanics, fluid mechanics, and sanitary engineering) is being reorganized and enlarged. With the development of the Transportation Center which emphasizes education and research in the broad fields of transportation, an extensive graduate program in transportation engineering and physical planning related to cities and regions has been introduced. To provide basic graduate education in the broad area of environmental engineering and public works which constitutes a major part of civil engineering, graduate work in the fields of construction, water resources, atmospheric pollution, and industrial and radioactive wastes has been developed. This enlarged civil engineering program provides an opportunity for graduate study with major work in sanitary engineering and the related basic sciences and to take work in physical planning. This integrates sanitary engineering studies with other activities of environment engineering and public works. Public works planning provides opportunity for students in any field of environmental engineering to obtain education relating their field to the other fields. Students interested in municipal engineering and public works planning and administration may take work in the areas of sanitary engineering, transportation, structures, water resources, planning, etc., to acquire a broad basic education. The aim of the program will be to emphasize the analytical and scientific aspects of engineering and the fundamental aspects of planning.

Research in progress in sanitary engineering deals with problems in fluid mechanics of sanitary engineering processes, radioactive wastes, tropical housing, long-range fallout from nuclear detonations, water purification by filtration, waste treatment and reclamation, and photosynthetic oxygenation. There are now three Ph. D. candidates working in the area joined by fluid

mechanics and radioactive wastes. The specific problems are concerned with the diffusion of radioactive wastes in open channels, tidal estuaries, and ground water flow. Experimental work is also being conducted on the development of ventilation louvres which will prevent admission of rain water while providing air passage. An experimental project is being conducted to determine long-range nuclear fallout. A research study is under way concerned with the problem of short filter runs in water plants on Lake Michigan during periods of high algae concentrations.

The Northwestern Technological Institute has also established a radionuclear laboratory which serves research work in the radiological phases of engineering. The laboratory is particularly well equipped for radioactivity measurements significant to sanitary engineering.

Research is now in progress on photosynthetic oxygenation and the development of design criteria for waste stabilization ponds. The Technological Institute's sanitary chemistry and biology laboratories are equipped for educational and research programs in the chemistry and biology of water, sewage, industrial wastes, and air. The fluid mechanics laboratory is equipped for research and education problems of fluid mechanics that are related to sanitary engineering. Research facilities are available at the nearby Chicago Sanitary District Plant and the North Shore water purification plants for pilot plant studies.

Faculty at Northwestern who have interest in sanitary engineering are: R. B. Banks, Chairman of the Civil Engineering Department, whose sanitary engineering interests center around the fluid mechanics aspects of the field; C. G. Bell, Associate Professor of Civil Engineering, whose primary research interests are disposal and control of wastes from reactors and nuclear detonations; M. B. Gamet, Professor of Civil Engineering, who is engaged in a study of algae shortened filter runs in plants taking water from Lake Michigan; W. S. Hamilton, Professor of Civil Engineering, whose interests are in fluid mechanics, hydrometeorology, and water resources; H. G. Gotaas, Professor of Civil Engineering, whose interests center around photosynthetic oxygenation of wastes, and waste reclamation; Emanuel Hurwitz, Lecturer in the Civil Engineering Department and Assistant Director of Laboratories, Sanitary District of Greater Chicago, whose chief research interests are in sanitary chemistry; Otto Koenigsberger, Visiting Lecturer in Civil Engineering, whose research interest is in city and regional planning and tropical housing, and J. A. Logan, Associate Director of the Transportation Center and Professor of Civil Engineering, whose sanitary engineering interests are in public health engineering, engineering administration, and environmental control.

* * * * *

ENVIRONMENTAL PROBLEMS CONNECTED WITH SPACE SHIP OCCUPANCY

About a year ago the problem of wastes handling for space travel was treated with tongue in cheek in the SED Newsletter. It now appears that there is more than just humor in the situation.

The Research Division, New York University, College of Engineering, is engaged in a study of the engineering techniques requisite to the handling, treatment, and disposal of the recycling of materials appearing as wastes and

by-products of human occupancy of the closed space. This research is being carried on for the Air Research and Development Command, United States Air Force.

As William T. Ingram, director of the project, stated it in a paper presented before the American Astronautical Society: "Men living in a closed space for an extended period of time must continue to function normally while performing whatever task is at hand. In a space ship there is no other supply of air; no other supply of water; food is limited by space; and cleansing operations for body, clothing, equipment, and premises minimal."

Emphasis in the research is being placed on those data that suggest handling of the wastes or the recycled materials without health hazard to the personnel, and the conversion of wastes so that they may be used in supplying oxygen, nutrients, and other beneficial products. At the same time it is borne in mind that materials that are harmful, toxic, or otherwise undesirable cannot remain in the closed environment. It is necessary to consider questions of seemingly trivial nature now, in order to be reasonably certain that nothing has been overlooked.

The experience to date is that questions under investigation compound as the studies lead toward tentative answers. In each approach these factors are always important: (1) the process must treat without failure; (2) the process wastes resulting from treatment must be adequately handled; (3) the equipment and materials must not introduce excessive cubage and weight.

It has been said that the problem of waste disposal has been over-emphasized since it should offer no problem to eject unwanted materials into the exterior void. It is not the purpose at this time to discuss the problems introduced by ejection; however, this one observation is made—mass balance could not be maintained if the wastes created by human habitation of closed space were to be disposed of by ejection and this balance is essential to accurate navigation. Mass conservation has been designated as a controlling factor in closed space ecology.

Combined medical and engineering investigations may eventually lead to a successful effort to create and maintain a closed space environment in which humans may live for extended periods of time under space equivalent conditions. This will require close liaison between medical and engineering research investigators working on the problem.

* * * * *

DID YOU KNOW THAT -

David H. Howells, formerly an assistant editor of the Division affairs section of this Journal in the Chicago Area, has recently been transferred from the Chicago Regional Office of the Public Health Service to Washington, D. C. Howells new assignment will be Assistant to the Chief of the Sewage Treatment Plant Construction Grant Program.

* * * * *

As of May 31, 1957, 1,052 communities had made applications for Federal grants for the construction of sewage treatment works under the provisions of Public Law 660. These 1,052 communities have requested $109 million of grant funds to construct projects with total estimated costs of $739 million. Grants under the Federal Act are limited to 30 percent of the total cost or $250,000, whichever is smaller.

Grants in the amount of $31.6 million for projects costing $132 million had been made to 384 communities to May 31. Fifty million dollars had been appropriated in Fiscal Year 1957 and $45 million for the year ending June 30, 1958.

* * * * *

Leo Weaver of the General Engineering Program, Public Health Service, was awarded a certificate of recognition for being selected as one of the outstanding young engineers in the Washington area for 1957. The award was part of the annual Engineers and Architects Day, sponsored by the District of Columbia Council of Engineering and Architectural Societies, Washington Academy of Sciences, Washington Section of the Institute of Radio Engineers, and D. C. Society of Professional Engineers.

* * * * *

The 10th anniversary of fluoridation in Evanston, Illinois, was marked in mid-February by the announcement that dental decay among the city's children is now much less than it was in 1947, the year fluorides were first added to the water supply. The director of the Evanston Fluoridation Study reported that six-year-olds, born after the start of the fluoridation program, and examined in 1954 and 1955, showed a reduction of 86.5 percent in the dental caries rate over the rate in the base year. Six-year-olds observed in 1952 showed a 68.5 percent drop in caries rate.

* * * * *

More than a dozen engineering students have been assigned to work for the PHS under the Commissioned Officers Summer Training Extern Program. This is the first year the program will be in effect for engineers. The program, designed to encourage promising young engineering students, is part of the PHS effort to bring more engineers into this field.

* * * * *

DID YOU KNOW THAT -
It is very difficult to write a Division Affairs Section if Members do not contribute news items. Make your contribution now to one of the Assistant Editors listed at the end of this section.

* * * * *

Three groups of Public Health Service Commissioned Reservists and active duty officers were assigned to duty as zone commanders and monitoring teams for the off-site radiological safety program at Camp Mercury, Nevada, for the Spring 1957 weapons test series. The first group reported at Camp Mercury on May 5. The second group reported on June 15, and the third group on August 1. The monitoring teams were stationed within a 10 to 300-mile radius of the test site.

* * * * *

Wesley E. Gilbertson, Assistant Chief, Division of Sanitary Engineering Services, PHS, has been designated as a representative on the United Nation's Economic Committee's Interagency Committee on International Water Programs.

* * * * *

William D. Shillinger, Sanitary Engineer with the Indiana State Board of Health, is president of the Northwestern Branch of the Indiana Section, ASCE. The vice-president is Leo Louis, Jr., Manager of the Gary-Hobart Water Corporation. Most of the members are connected with the industries in that portion of the State, although a goodly representation is also had from consulting firms, contractors, University of Notre Dame, and governmental units.

A varied program has been planned for the coming year for this active branch of 175 members. Manufacture and use of plastic pipe, Federal Highway Program, Geological History of the Great Lakes Region, Purdue-Calumet Redevelopment Program, and the Hudson River Bridge Erection by the American Bridge Company are a few of the programs planned for the near future.

Donald A Pecsok, Senior Sanitary Engineer, PHS, of the Robert A. Taft Sanitary Engineering Center, was the speaker at the May 21 meeting. His talk on the sanitary engineering aspects of nuclear energy was down to earth and aroused the interest of all the members in this phase of civil engineering. He discussed the beneficial uses of nuclear energy by the sanitary engineer as well as many of the problems arising through the increased use of radioactive materials. The interest of the members in the subject resulted in many questions and a lively discussion following his talk.

* * * * *

The Engineering and Sanitation Sections of the Kansas State Board of Health, after being quartered for many years in Marvin Hall at the University of Kansas, have recently moved from Lawrence to Topeka, Kansas. Their new offices are in the Capitol Offices Building.

* * * * *

A Division of Hydraulics and Sanitary Engineering has been formed by the Philadelphia Section of the American Society of Civil Engineers. At the organizational meeting, a temporary Executive and Program Committee consisting of Walter A. Lyon, Chairman; Romeo Falciani, Vice-Chairman; and William T. Savage, Secretary, was elected. The Division will meet on the third Thursdays of September, November, January, March, and May with field trips planned in addition to the regular meetings, at the Engineers Club, 1317 Spruce Street, Philadelphia, Pa. So far some 84 engineers have indicated an interest in participating in the activities of the Division. It is hoped that the Division will serve as a focus of professional interest for Hydraulic and Sanitary Engineers in the Delaware Valley area and environs.

* * * * *

In 1957, five Engineers availed themselves of the Sanitary Engineering Research Fellowship program of the PHS. This program, started in 1957, is

available to persons desiring advance study in the broad field of Sanitary Engineering. Applicants may have basic training in engineering or related sciences, biological, chemical, physical. This fellowship program is provided to increase the number of engineers and scientists qualified to conduct independent research in problems of environmental sanitation. Information on fellowships which are available is as follows:

PREDOCTORAL RESEARCH FELLOWSHIPS: Available to qualified persons with bachelor's or master's degree, or equivalent training, whose proposed programs lead toward the M.S. or Ph.D. degree in sanitary engineering or related sciences. Basic stipend: First year, $1,600; intermediate year, $1,800; terminal year, $2,000. Dependency allowance of $350 for spouse and each dependent child is also provided as well as basic tuition and certain travel expenses.

POSTDOCTORAL RESEARCH FELLOWSHIPS: Available to qualified persons holding Ph.D., D.Sc., or equivalent degrees in the sanitary engineering or related sciences, who show unusual interest in specialized scientific fields related to environmental sanitation and evidence that they expect to follow a career in related research. The stipend is $3,800 for the first year plus $350 for spouse and each dependent child, along with any necessary tuition and certain travel expenses. The sponsoring department may receive $500 reimbursement for expenses of providing training. The basic stipend is increased $400 for the second year of award, and an additional $400 for the third year.

SPECIAL RESEARCH FELLOWSHIPS: Available to qualified applicants with a doctor's degree or equivalent in sanitary engineering or related sciences who have demonstrated unusual competence for research and require specialized training for a specific problem. Stipend and allowances are determined at the time of review.

Application may be made at any time with final action and advice to the applicant within 90 days. Information and application blanks may be obtained from the Chief, Research Fellowships Branch, Division of Research Grants, National Institutes of Health, Bethesda 14, Maryland.

* * * * *

Five grants totaling $38,328 for demonstration projects in the field of air pollution control were awarded under the Air Pollution Research and Technical Assistance Act of 1955 (Public Law 159), the first demonstration project grants to be made under the Act. Included were projects for demonstrating the use of meteorology in large-scale air pollution problems, for determining the effect of uranium processing operations on radioactivity levels, and the development of an air pollution study in a major interstate metropolitan area. Grants and sums were made to: California State Department of Public Health ($16,730); Colorado State Department of Public Health ($6,025); Illinois Department of Public Health ($5,850); Indiana State Board of Health ($4,700); and Texas, El Paso City-County Health Unit ($5,023).

* * * * *

About 300 sanitary engineers have been certified by the American Sanitary Engineering Intersociety Board under the "grandfather" clause. The clause

permits certification without examination of sanitary engineers with 15 years of satisfactory experience, a degree, professional registration, and certain other qualifications. The clause was to have expired July 1, but the Board extended the deadline until October 1 to accommodate members of the American Institute of Chemical Engineers, a newly voted sponsoring group.

* * * * *

Mr. F. J. Maier was named chairman of the Subcommittee on Fluoridation Analysis of the Standard Methods Board of the American Water Works Association.

* * * * *

Of the 440 applications for awards to individuals for graduate training in public health under the Health Amendments Act of 1956 (P.L. 911), approximately one-third (143) were in the category of environmental sanitation. Nearly all the applications were for the 1957 fall semester—58 from engineers, 71 from sanitarians, and 14 from chemists, biologists, and industrial hygienists. In addition, there were 9 applications for direct traineeship aid under the provisions of the Air Pollution Research and Technical Assistance Act of 1955 (P.L. 159)—5 engineers, 1 sanitarian, 2 meteorologists, and 1 chemist. The processing of these applications is now taking place.

* * * * *

"The Radiological Health Handbook," compiled and edited by Simon Kinsman and others of the Robert A. Taft Sanitary Engineering Center, is now available from the Office of Technical Services, U. S. Department of Commerce, Washington 25 D. C., at $3.75 per copy.

* * * * *

The scarcity of water for the seminomadic Navajos is a major factor in their high enteric disease rate. On the average, each family has to haul water 8 to 10 miles. This problem will be given attention as the result of recent action by the Navajo Tribal Council in authorizing a $3,000,000 expenditure for water development.

* * * * *

Mr. Ray Raneri, Robert A. Taft Sanitary Engineering Center, was elected president of the Cincinnati Section of the American Society of Civil Engineers.

* * * * *

Mr. Peter P. Rowan, formerly chief of the Engineering and Construction Section, Fairfax County, Virginia, Division of Sanitation, has recently accepted a position with the Sewage Treatment Plant Construction Grant Program, Division of Sanitary Engineering Services, Public Health Service.

* * * * *

Mr. James G. Terrill, Jr., Chief, Radiological Health Program of the Public Health Service, will serve as the representative of the ASCE on the program committee for the Third Nuclear Congress, to be held late in 1958 in Chicago.

* * * * *

Mr. Carl Zillig has been appointed Superintendent of the Little Miami Sewage Works for the Metropolitan Cincinnati Sewage Disposal Program.

* * * * *

Mr. Arthur Caster, Secretary of the Sanitary Division has been elected Vice President of the Cincinnati Chapter of the Ohio Society of Professional Engineers and Director of the Cincinnati Engineering Society.

* * * * *

LETTER FROM THE EDITOR:

Dear Fellow Sanitary Engineers:

This issue marks the end of my responsibility as Editor of the Division Affairs Section of the SED Journal. I have asked to be relieved of this responsibility because I feel that the best interests of the Society will be served through periodic changes which bring new ideas and fresh viewpoints to committees.

It has been most interesting and a pleasure to serve you as a news editor. I hope that the past issues have been of interest to you for we have used material and format, especially to cover miscellaneous news items, in an informal, easy reading manner. I have been disappointed that there has not been greater participation by the membership which would have permitted better coverage but perhaps this will change with the passage of time.

David Howells has agreed to accept the responsibility for future issues of the Division Affairs Section. He has been a faithful assistant editor for the past few years and it is my hope that you will make his job easy by submitting news items about yourself, your friends, and the sanitary engineering activity in your area. A variety of news articles will make an interesting section—and your area will get some recognition for activity which contributes to the success of the profession. If you do not cooperate the Division Affairs Section cannot be balanced for all news items will come from a single source.

Sincerely,

Paul W. Reed

Please cooperate by sending news items of interest to:

David H. Howells, EDITOR
Division Affairs Section, SED Journal
c/o Division of Sanitary Engineering Services
Public Health Service
Department of Health, Education, and Welfare
Washington 25, D. C.

ASSISTANT EDITORS:

Gilbert H. Dunstan
Department of Civil Engineering
Washington State Institute of Technology
Pullman, Washington

E. R. Hendrickson
Department of Civil Engineering
University of Florida
Gainesville, Florida

Harold J. Karsten
Infilco, Inc.
6315 Brookside Plaza
Kansas City, Missouri

D. G. Larkin
512 Sixteenth Street
Oakland 23, California

Walter A. Lyon
Room 630, City Hall Annex
Philadelphia 7, Penna.

John C. McMahon
U. S. Public Health Service
69 West Washington Street
Chicago 2, Illinois

Carl Zillig
1600 Gest Street
Cincinnati 4, Ohio

The technical papers published in the past year are identified by number below. Technical-division sponsorship is indicated by an abbreviation at the end of each Paper Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Pipeline (PL), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways and Harbors (WW), divisions. Papers sponsored by the Board of Direction are identified by the symbols (BD). For titles and order coupons, refer to the appropriate issue of "Civil Engineering." Beginning with Volume 82 (January 1956) papers were published in Journals of the various Technical Divisions. To locate papers in the Journals, the symbols after the paper numbers are followed by a numeral designating the issue of a particular Journal in which the paper appeared. For example, Paper 1113 is identified as 1113 (HY6) which indicates that the paper is contained in the sixth issue of the Journal of the Hydraulics Division during 1956.

VOLUME 82 (1956)

AUGUST: 1034(HY4), 1035(HY4), 1036(HY4), 1037(HY4), 1038(HY4), 1039(HY4), 1040(HY4), 1041(HY4)^c, 1042(PO4), 1043(PO4), 1044(PO4), 1045(PO4), 1046(PO4)^c, 1047(SA4), 1048 (SA4)^c, 1049(SA4), 1050(SA4), 1051(SA4), 1052(HY4), 1053(SA4).

SEPTEMBER: 1054(ST5), 1055(ST5), 1056(ST5), 1057(ST5), 1058(ST5), 1059(WW4), 1060(WW4), 1061(WW4), 1062(WW4), 1063(WW4), 1064(SU2), 1065(SU2), 1066(SU2)^c, 1067(ST5)^c, 1068 (WW4)^c, 1069(WW4).

OCTOBER: 1070(EM4), 1071(EM4), 1072(EM4), 1073(EM4), 1074(HW3), 1075(HW3), 1076(HW3), 1077(HY5), 1078(SA5), 1079(SM4), 1080(SM4), 1081(SM4), 1082(HY5), 1083(SA5), 1084(SA5), 1085(SA5), 1086(PO5), 1087(SA5), 1088(SA5), 1089(SA5), 1090(HW3), 1091(EM4)^c, 1092 (HY5)^c, 1093(HW3)^c, 1094(PO5)^c, 1095(SM4)^c.

NOVEMBER: 1096(ST6), 1097(ST6), 1098(ST6), 1099(ST6), 1100(ST6), 1101(ST6), 1102(IR3), 1103 (IR3), 1104(IR3), 1105(IR3), 1106(ST6), 1107(ST6), 1108(ST6), 1109(AT3), 1110(AT3)^c, 1111(IR3)^c; 1112(ST6)^c.

DECEMBER: 1113(HY6), 1114(HY6), 1115(SA6), 1116(SA6), 1117(SU3), 1118(SU3), 1119(WW5), 1120(WW5), 1121(WW5), 1122(WW5), 1123(WW5), 1124(WW5)^c, 1125(BD1)^c, 1126(SA6), 1127 (SA6), 1128(WW5), 1129(SA6)^c, 1130(PO6)^c, 1131(HY6)^c, 1132(PO6), 1133(PO6), 1134(PO6), 1135(BD1).

VOLUME 83 (1957)

JANUARY: 1136(CP1), 1137(CP1), 1138(EM1), 1139(EM1), 1140(EM1), 1141(EM1), 1142(SM1), 1143(SM1), 1144(SM1), 1145(SM1), 1146(ST1), 1147(ST1), 1148(ST1), 1149(ST1), 1150(ST1), 1151(ST1), 1152(CP1)^c, 1153(HW1), 1154(EM1)^c, 1155(SM1)^c, 1156(ST1)^c, 1157(EM1), 1158 (EM1), 1159(SM1), 1160(SM1), 1161(SM1).

FEBRUARY: 1162(HY1), 1163(HY1), 1164(HY1), 1165(HY1), 1166(HY1), 1167(HY1), 1168(SA1), 1169(SA1), 1170(SA1), 1171(SA1), 1172(SA1), 1173(SA1), 1174(SA1), 1175(SA1), 1176(SA1), 1177(HY1)^c, 1178(SA1), 1179(SA1), 1180(SA1), 1181(SA1), 1182(PO1), 1183(PO1), 1184(PO1), 1185(PO1)^c.

MARCH: 1186(ST2), 1187(ST2), 1188(ST2), 1189(ST2), 1190(ST2), 1191(ST2), 1192(ST2)^c, 1193 (PL1), 1194(PL1), 1195(PL1).

APRIL: 1196(EM2), 1197(HY2), 1198(HY2), 1199(HY2), 1200(HY2), 1201(HY2), 1202(HY2), 1203 (SA2), 1204(SM2), 1205(SM2), 1206(SM2), 1207(SM2), 1208(WW1), 1209(WW1), 1210(WW1), 1211(WW1), 1212(EM2), 1213(EM2), 1214(EM2), 1215(PO2), 1216(PO2), 1217(PO2), 1218 (SA2), 1219(SA2), 1220(SA2), 1221(SA2), 1222(SA2), 1223(SA2), 1224(SA2), 1225(PO)^c, 1226 (WW1)^c, 1227(SA2)^c, 1228(SM2)^c, 1229(EM2)^c, 1230(HY2)^c.

MAY: 1231(ST3), 1232(ST3), 1233(ST3), 1234(ST3), 1235(IR1), 1236(IR1), 1237(WW2), 1238(WW2), 1239(WW2), 1240(WW2), 1241(WW2), 1242(WW2), 1243(WW2), 1244(HW2), 1245(HW2), 1246 (HW2), 1247(HW2), 1248(WW2), 1249(HW2), 1250(HW2), 1251(WW2), 1252(WW2), 1253(IR1), 1254(ST3), 1255(ST3), 1256(HW2), 1257(IR1)^c, 1258(HW2)^c, 1259(ST3)^c.

JUNE: 1260(HY3), 1261(HY3), 1262(HY3), 1263(HY3), 1264(HY3), 1265(HY3), 1266(HY3), 1267 (PO3), 1268(PO3), 1269(SA3), 1270(SA3), 1271(SA3), 1272(SA3), 1273(SA3), 1274(SA3), 1275 (SA3), 1276(SA3), 1277(HY3), 1278(HY3), 1279(PL2), 1280(PL2), 1281(PL2), 1282(SA3), 1283 (HY3)^c,1284(PO3), 1285(PO3), 1286(PO3), 1287(PO3)^c, 1288(SA3)^c.

JULY: 1289(SM3), 1290(EM3), 1291(EM3), 1292(EM3), 1293(EM3), 1294(HW3), 1295(HW3), 1296(HW3), 1297(HW3), 1298(HW3), 1299(SM3), 1300(SM3), 1301(SM3), 1302(ST4), 1303 (ST4), 1304(ST4), 1305(SU1), 1306(SU1), 1307(SU1), 1308(ST4), 1309(SM3), 1310(SU1)^c, 1311(EM3)^c, 1312(ST4), 1313(ST4), 1314(ST4), 1315(ST4), 1316(ST4), 1317(ST4), 1318 (ST4), 1319(SM3)^c, 1320(ST4), 1321(ST4), 1322(EM3), 1323(AT1), 1324(AT1), 1325(AT1), 1326(AT1), 1327(AT1), 1328(AT1)^c, 1329(ST4)^c.

AUGUST: 1330(HY4), 1331(HY4), 1332(HY4), 1333(SA4), 1334(SA4), 1335(SA4), 1336(SA4), 1337(SA4), 1338(SA4), 1339(CO1), 1340(CO1), 1341(CO1), 1342(CO1), 1343(CO1), 1344(PO4), 1345(HY4), 1346(PO4)^c, 1347(BD1), 1348(HY4)^c, 1349(SA4)^c, 1350(PO4), 1351(PO4).

---

c. Discussion of several papers, grouped by Divisions.

PROCEEDINGS OF THE SOCIETY

HAROLD T. LARSEN
Manager of Technical Publications

PAUL A. PARISI
Editor of Technical Publications